EPA/DOE

MINE WASTE TECHNOLOGY PROGRAM

Technology Testing for Tomorrow's Solutions

MINE WASTE TECHNOLOGY PROGRAM

EPA DOE Montana Tech Implemented by MSE Technology Applications, Inc.

EPA/DOE

MINE WASTE TECHNOLOGY PROGRAM

2002 ANNUAL REPORT

Prepared by:

MSE Technology Applications, Inc.
P.O. Box 4078
Butte, Montana 59702

Mine Waste Technology Program
Interagency Agreement Management Committee
IAG ID NO. DW89938870-01-0

Prepared for:

U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 46268

and

U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 10940
Pittsburgh, Pennsylvania 15236-0940
Contract No. DE-AC22-96EW96405

CONTENTS

VISION STATEMENT FOR THE BUTTE MINE WASTE TECHNOLOGY PROGRAM

THE PROBLEM

Mining activities in the United States (not counting coal) produce between 1 and 2 billion tons of mine waste annually. These activities include extraction and beneficiation of metallic ores, phosphate, uranium, and oil shale. Over 130,000 of these noncoal mines, concentrated largely in nine western states, are responsible for polluting over 3,400 miles of streams and over 440,000 acres of land. About seventy of these sites are on the National Priority List for Superfund remediation. In the 1985 Report to Congress on the subject, the total noncoal mine waste volume was estimated at 50 billion tons, with 33% being tailings, 17% dump/heap leach wastes and mine water, and 50% surface and underground wastes. Since many of the mines involve sulfide minerals, the production of acid mine drainage (AMD) is a common problem from these abandoned mine sites. The cold temperatures in the higher elevations and heavy snows frequently prevent winter site access. The combinations of acidity, heavy metals, and sediment have severe detrimental environmental impacts on the delicate ecosystems in the West.

PHILOSOPHY/VISION

End-of-pipe treatment technologies, while essential for short-term control of environmental impact from mining operations, are a stopgap approach for total remediation. Efforts need to be made on improving the end-of-pipe technologies to reduce trace elements to low levels for applications in ultra-sensitive watersheds and for reliable operation in unattended, no power situations. The concept of pollution prevention, emphasizing at-source control and resource recovery, is the approach of choice for the long-term solution. Our objective in the Butte Mine Waste Technology Program is not to assess the environmental impacts of the mining activities, but it is to develop and prove technologies that provide satisfactory short- and long-term solutions to the remedial problems facing abandoned mines often in remote sites and the ongoing compliance problems associated with active mines, not only in Montana but throughout the United States.

APPROACH

There are priority areas for research, in the following order of importance:

Source Controls, Including In Situ Treatments and Predictive Techniques
It is far more effective to attack the problem at its source than to attempt to deal with diverse and dispersed wastes, laden with wide varieties of metal contaminants. At-source control technologies, such as sulfate-reducing bacteria; biocyanide oxidation for heap leach piles; transport control/pathway interruption techniques, including infiltration controls, sealing, grouting, and plugging by ultramicrobiological systems; and AMD production prediction and control techniques should strive toward providing a permanent solution, which of course is the most important goal of the program.

Treatment Technologies
Improvements in short-term end-of-pipe treatment options are essential for providing immediate alleviation of some of the severe environmental problems associated with mining, and particularly with abandoned metal mines.

Because immediate solutions may be required, this area of research is extremely important for effective environmental protection.

Resource Recovery

In the spirit of pollution prevention, much of the mining wastes, both AMD (e.g., *over 25 billion gallons* of Berkeley Pit water) and the billions of tons of mining/beneficiation wastes, represent a potential resource as they contain significant quantities of heavy metals. While remediating these wastes, it may be feasible to incorporate resource recovery options to help offset remedial costs.

THE PARTNERSHIPS

In these days of ever-tightening budgets, it is important that we leverage our limited funding with other agencies and with private industry. The Bureau of Land Management and Forest Service actively participate by providing sites for demonstrations of the technologies. It is important where these technologies have application to active mining operations to achieve cost-sharing partnerships with the mining industry to test the technologies at their sites. Fortunately, the program has strong cooperation from industry. Within the U.S. Environmental Protection Agency (EPA), the Butte program is coordinated and teamed, where appropriate, with the Superfund Innovative Technology Evaluation (SITE) program to leverage the funding and maximize the effectiveness of both programs. We have strong interaction, cooperation, and assistance from the mining teams in the EPA Regional Offices, especially Regions 7, 8, 9, and 10. Several joint projects are underway, and more are planned.

A considerable resource and willing partner is the University system (such as Montana Tech of the University of Montana, University of Montana–Missoula, Montana State University–Bozeman, and the Center for Biofilm Engineering), which can conduct the more basic type of research related to kinetics, characterization, and bench-scale tests at minimal cost to the program, while at the same time providing environmental education that will be useful to the region and to the Nation. The Butte Mine Waste Technology Program supports cooperative projects between the educational system and the mining industry, where teams of students conduct research of mine site-specific problems, often with monetary support from the industry. The results are made available to the industry as a whole and to the academic community.

THE SCIENCE

The research program is peer-reviewed annually by the Technical Integration Committee (TIC), who technically reviews all ongoing and proposed projects. The TIC is composed of technical experts from EPA and the cooperating agencies, academia, environmental stakeholders, and industry and their consultants. Final reports are additionally peer-reviewed in accordance with EPA's strict policy for scientific products.

Roger C. Wilmoth
Chief, Industrial Multimedia Branch
Sustainable Technology Division
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
(MS 445)
26 W. Martin Luther King Drive
Cincinnati, OH 45268

PROGRAM MANAGER'S EXECUTIVE SUMMARY

The Mine Waste Technology Program (MWTP) Annual Report for fiscal 2002 summarizes the results and accomplishments for the various activities within the Program. The MWTP has met its goals by providing assistance to the public and forming cooperative teams drawn from government, industry, and private citizens. The funds expended have returned tangible results, providing tools for those faced with mine waste remediation challenges.

After 12 years, everyone involved with the MWTP can look with pride to the Program's success. Technology development and basic research has proceeded successfully through the efforts of MSE Technology Applications, Inc. (MSE) and its prime subcontractor Montana Tech of the University of Montana (Montana Tech).

MSE has developed thirty-seven field-scale demonstrations, several of which are attracting attention from industry and public stakeholders involved in the cleanup of mine wastes.

Montana Tech has developed twenty-four bench-scale projects, six of which are ongoing during 2002. This cooperative effort provides cutting edge research for the program as well as educational opportunities.

Numerous activities are associated with the development of a field-scale demonstration. Among these activities is the need to acquire federal and state permits, secure liability limiting access agreements, develop and adhere to health and safety operation plans, and comply with the National Environmental Policy Act and other federal and state environmental oversight statutes.

The Program has received substantial support from state and federal agencies, the mining industry, environmental organizations, and numerous associations interested in mining and development of natural resources at state, regional, and national levels.

Montana Tech continued the post-graduate degree program with a mine waste emphasis. The quality of short courses offered by Montana Tech is becoming highly recognized by the mining industry and mine waste remediation community. Graduates of the program are fast becoming leaders for industry and government agencies helping to promote technology usage and acceptance worldwide.

The MWTP recognizes its major accomplishments and looks forward to providing new and innovative technologies; meeting the challenges of mine waste remediation; and providing economical, permanent solutions to the nation's mining waste problems.

Jeff LeFever
MSE MWTP Program Manager

INTRODUCTION

Mining waste generated by active and inactive mining production facilities and its impact on human health and the environment are a growing problem for Government entities, private industry, and the general public. The nation's reported volume of mine waste is immense. Presently, there are more than sixty mining impacted sites on the U.S. Environmental Protection Agency's National Priorities List.

Environmental impacts associated with inactive and abandoned mines are common to mining districts around the country, as shown in Table 1.

Total estimated remediation costs for these states range from $4 to $45 billion.

Health effects from the predominate contaminants in mine waste range from mild irritants to proven human carcinogens, such as cadmium and arsenic. The large volume of mine wastes and consequential adverse environmental and human health effects indicates an urgency for cleanup of abandoned, inactive, and active mining facilities. The environmental future of the United States depends in part on the ability to deal effectively with mine waste problems of the past and present, and more importantly, to prevent mine waste problems in the future.

The fiscal year (FY) 1991 Congressional Appropriation allocated $3.5 million to establish a pilot program in Butte, Montana, for evaluating and testing mine waste treatment technologies. The Mine Waste Technology Program (MWTP) received additional appropriations of $3.5 million in FY91, $3.3 million in FY94, $5.9 million in FY95, $2.5 million in FY96, $7.5 million in FY97, $6.0 million in FY98 and FY99, $4.3 million in FY00, $3.9 million in FY01, and $3.9 million in FY02.

The projects undertaken by this Program focus on developing and demonstrating innovative technologies at both the bench- and pilot-scale that treat wastes to reduce their volume, mobility, or toxicity. Fifty percent of the budget is allocated to focus areas such as: 1) source control for preventing metal leaching and acid mine drainage; 2) techniques for treating low-flow metal laden/acid mine drainage in remote settings. The focus areas can be obtained from www.epa.gov/ORD/NRMRL/std/mtb new proposals (link). To convey the results of these demonstrations to the user community, the mining industry, and regulatory agencies, MWTP includes provisions for extensive technology transfer and educational activities. This report summarizes the progress of the MWTP in FY02.

Table 1. Number and types of sites and abandoned mine lands in Western Region.

State	Estimated Number of Sites or Land Areas	Classification and Estimated Number
Alaska	10,910 sites	mine dumps - 1,000 acres disturbed land - 27,680 acres mine openings - 500 hazardous structures - 300
Arizona	95,000 sites	polluted water - 2,002 acres mine dumps - 40,000 acres disturbed land - 96,652 acres mine openings - 80,000
California	11,500 sites	polluted water - 369,920 acres mine dumps - 171 acres mine openings - 1,685
Colorado	20,229 sites covering 26,584 acres	polluted water - 830,720 acres mine dumps - 11,800 acres disturbed land - 13,486 acres mine openings - 20,229 hazardous structures - 1,125
Idaho	8,500 sites covering 18,465 acres	polluted water - 84,480 acres mine dumps - 3,048 acres disturbed land - 24,495 acres mine openings - 2,979 hazardous structures - 1,926
Michigan	400–500 sites	Accurate information not available.
Montana	19,751 sites covering 11,256 acres	polluted water - 715,520 acres mine dumps - 14,038 acres disturbed land - 20,862 acres mine openings - 4,668 hazardous structures - 1,747
Nevada	400,000 sites	Accurate information not available.
New Mexico	7,222 sites covering 13,585 acres	polluted water - 44,160 acres mine dumps - 6,335 acres disturbed land - 25,230 acres mine openings - 13,666 hazardous structures - 658
Oregon	3,750 sites	polluted water - 140,800 acres mine dumps - 180 acres disturbed land - 61,000 acres mine openings - 3,750 hazardous structures - 695
South Dakota	4,775 acres	Accurate information not available.
Texas	17,300 acres	Accurate information not available.
Utah	14,364 sites covering 12,780 acres	polluted water - 53,120 acres mine dumps - 2,369 acres disturbed land - 18,873 acres mine openings - 14,364 hazardous structures - 224
Wisconsin	200 acres	Accurate information not available.
Wyoming	5,000 acres	Accurate information not available.

Information was collected from the following sources and is only an estimate of the acid mine drainage problem in the West.

-Bureau of Land Management
-Bureau of Mines
-Mineral Policy Center
-National Park Service
-U.S. Department of Agriculture
-U.S. Department of the Interior
-U.S. Forest Service
-U.S. Geological Survey
-U.S. General Accounting Office
-Western Governor's Association Mine Waste Task Force Study

PROGRAM OVERVIEW

FISCAL 2002 PROGRAM

This Mine Waste Technology Program (MWTP) annual report covers the period from October 1, 2001, through September 30, 2002. This section of the report explains the MWTP organization and operation.

MISSION

The mission of the MWTP is to provide engineering solutions to national environmental issues resulting from the past practices of mining and smelting metallic ores. In accomplishing this mission, the MWTP develops and conducts a program that emphasizes treatment technology development, testing and evaluation at bench- and pilot-scale, and an education program that emphasizes training and technology transfer. Evaluation of the treatment technologies focuses on reducing the mobility, toxicity, and volume of waste; implementability; short- and long-term effectiveness; protection of human health and the environment; community acceptance; and cost reduction.

The statement of work provided in the Interagency Agreement between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy identifies six activities to be completed by MWTP. The following descriptions identify the key features of each and the organization performing the activity.

ACTIVITY I: ISSUES IDENTIFICATION

Montana Tech of the University of Montana (Montana Tech) is documenting mine waste technical issues and innovative treatment technologies. These issues and technologies are then screened and prioritized in volumes related to a specific mine waste problem. Technical issues of primary interest are Mobile Toxic Constituents—Water/Acid Generation; Mobile Toxic Constituents–Air, Cyanide, Nitrate, Arsenic, Pyrite, Selenium, and Thallium; and Pit Lakes. Wasteforms reviewed related to these issues include point- and nonpoint-source acid drainage, abandoned mine acid drainage, streamside tailings, impounded tailings, priority soils, and heap leach-cyanide/acid tailings. In addition, under this task Montana Tech produced a CD-ROM based summary of the Program in two volumes—Annual Report and Activities in Depth. The CDs can be obtained from the personnel listed in the Contacts Section of this report. The Annual Report data is also available on the web at www.epa.gov/ORD/NRMRL/std/mtb.

ACTIVITY II: QUALITY ASSURANCE

The MWTP operates under an EPA approved Quality Management Plan (QMP). The QMP is available on www.epa.gov/ORD/NRMRL/std/mtb. This plan provides specific instructions for data gathering, analyzing, and reporting for all MWTP activities.

ACTIVITY III: PILOT-SCALE DEMONSTRATIONS

Pilot-scale demonstration topics were chosen after a thorough investigation of the associated technical issue was performed, the specific wasteform to be tested was identified, peer review was conducted, and sound engineering and cost determination of the demonstration were formulated.

MSE continued eighteen field-scale demonstrations during fiscal 2002. Four field demonstrations were completed, i.e., Projects 12, 27, 31, and 35. Three projects were begun: 1) Contaminant Speciation in Riparian Soils; 2) Long-Term Monitoring of a Permeable Treatment Wall; and 3) Electrochemical Tailings Cover.

ACTIVITY IV: BENCH-SCALE EXPERIMENTS

Montana Tech successfully completed seven projects during fiscal 2002, i.e., Projects 13, 14, and 16 through 20. Three projects were begun: 1) Organic Matter Degradation Rate in a Sulfate Reducing Wetland; 2) Sulfate Removal Technology Development; and 3) Algal Bioremediation of Berkeley Pit Lake System – Phase III.

ACTIVITY V: TECHNOLOGY TRANSFER

MSE is responsible for preparing and distributing reports for the MWTP. These include routine weekly, monthly, quarterly, and annual reports; technical progress reports; and final reports for all MWTP activities. MSE also publicizes information developed under MWTP in local, regional, and national publications. Other means of information transfer include public meetings, workshops, and symposiums.

ACTIVITY VI: EDUCATIONAL PROGRAMS

Montana Tech has developed a post-graduate degree program with a mine waste emphasis. The program contains elements of geophysical, hydrogeological, environmental, geochemical, mining and mineral processing, extractive metallurgical, and biological engineering.

ORGANIZATIONAL STRUCTURE

MANAGEMENT ROLES AND RESPONSIBILITIES

Management of the Mine Waste Technology Program (MWTP) is specified in the Interagency Agreement. The roles and responsibilities of each organization represented are described below. The MWTP organizational chart is presented in Figure 1.

U.S. ENVIRONMENTAL PROTECTION AGENCY

The Director of the National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio, is the principal U.S. Environmental Protection Agency Office of Research and Development representative on the Interagency Agreement Management committee. NRMRL personnel are responsible for management oversight of technical direction, quality assurance, budget, schedule, and scope.

DEPARTMENT OF ENERGY

The Director of the National Energy Technology Laboratory (NETL) is the principal U.S. Department of Energy (DOE) representative on the Interagency Agreement Management committee. NETL personnel provide contract oversight for the MWTP. MSE Technology Applications, Inc. (MSE) is responsible to NETL for adherence to environmental, safety and health requirements; regulatory requirements; National Environmental Protection Act requirements, and conduct of operations of all projects.

MSE TECHNOLOGY APPLICATIONS, INC.

MSE, under contract with DOE, is the principal performing contractor for MWTP. The MWTP Program Manager is the point of contact for all mine waste activities. The Program Manager is responsible for program management and coordination, program status reporting, funds distribution, and communications.

An MSE project manager has been assigned to each MWTP project and is responsible to the MWTP Program Manager for overall project direction, control, and coordination. Each project manager is responsible for implementing the project within the approved scope, schedule, and cost. MSE also provides all staff necessary for completing Activities II, III and V and oversight of Activities III, IV, and VI.

MONTANA TECH OF THE UNIVERSITY OF MONTANA

As a subcontractor to MSE, Montana Tech of the University of Montana is responsible to the MWTP Program Manager for all work performed under Activities I, IV, and VI. The responsibility for overall project direction, control, and coordination of the work to be completed by Montana Tech is assigned to the MWTP Montana Tech Project Manager.

TECHNICAL INTEGRATION COMMITTEE

The Technical Integration Committee (TIC) serves several purposes in the MWTP organization: 1) TIC reviews new proposals and ranks them at a meeting held in Butte, Montana; 2) it reviews progress in meeting the goals of the MWTP and alerts the Interagency Agreement Management Committee to pertinent technical concerns; 3) it provides information on the needs and requirements of the entire mining waste technology user community; and 4) it assists with evaluating technology demonstrations as well as technology transfer. This committee is comprised of representatives from both the public and private sectors.

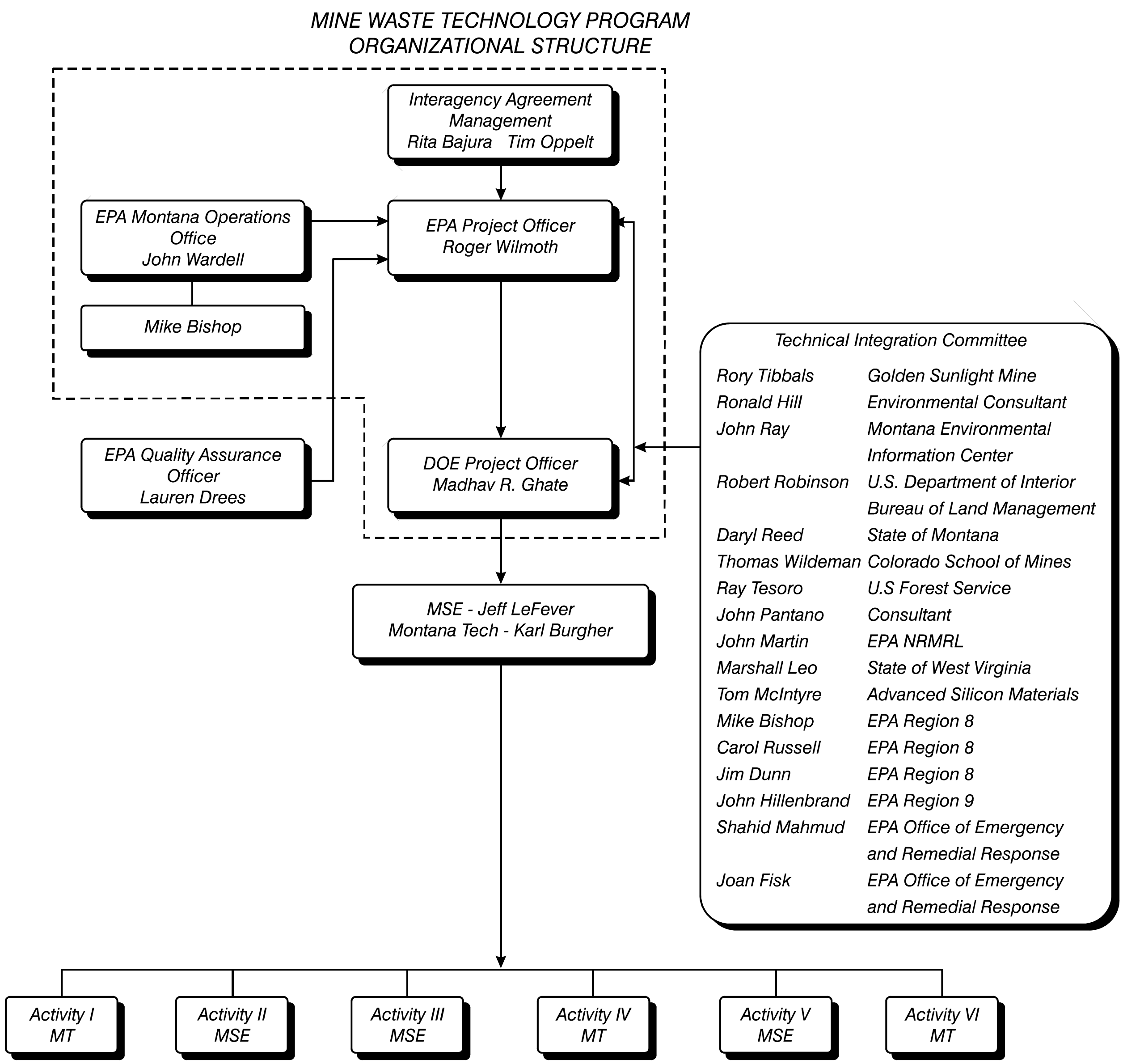

Figure 1. MWTP organizational chart.

DESCRIPTIONS, ACCOMPLISHMENTS, AND FUTURE DIRECTION

This section describes the Mine Waste Technology Program (MWTP) Activities I through VI and includes project descriptions, major project accomplishments during fiscal 2002, and future project direction.

ACTIVITY I OVERVIEW—ISSUES IDENTIFICATION

This activity focuses on documenting mine waste technical issues and identifying innovative treatment technologies. Issues and technologies are screened and prioritized in volumes related to a specific mine waste problem/market.

Following completion of a volume, appendices are prepared. Each appendix links a candidate technology with a specific site where such a technology might be applied. The technology/site combinations are then screened and ranked.

Technical Issue Status

The status of the volumes approved for development includes:

- Volume 1, Mobile Toxic Constituents—Water and Acid Generation, complete.
- Volume 2, Mobile Toxic Constituents—Air, complete.
- Volume 3, Cyanide, complete.
- Volume 4, Nitrate, complete.
- Volume 5, Arsenic, complete.
- Volumes 1-5 Summary Report, complete.
- Volume 6, Pyrite, complete.
- Volume 7, Selenium, complete.
- Volume 8, Thallium, complete.
- Volume 9, Pit Lakes, in progress.

The status of the appendices for approved projects includes:

- Volume 1, Appendix A (Remote Mine Site), complete.
- Volume 1, Appendix B (Grouting), complete.
- Volume 1, Appendix C (Sulfate-Reducing Bacteria), complete.
- Volume 3, Appendix A (Biocyanide), complete.
- Volume 4, Appendix A (Nitrate), complete.

These documents can be reviewed at the web site, www.epa.gov/ORD/NRMRL/std/mtb.

ACTIVITY II OVERVIEW—QUALITY ASSURANCE

The objective of this activity is to provide support to individual MWTP projects by ensuring all data generated is legally and technically defensible and that it supports the achievement of individual project objectives. The primary means of carrying out this activity is the Quality Assurance Project Plan, which is written for each project. This plan specifies the quality requirements the data must meet, states the project objectives, describes all sampling and measurement activities, and contains standard operating procedures, when applicable. Other functions of this activity include reviewing technical systems, validating data, implementing corrective action, and reporting to project management.

The U.S. Environmental Protection Agency approved the MWTP Quality Management Plan in 200l.

ACTIVITY III OVERVIEW— PILOT-SCALE DEMONSTRATIONS

The objective of this activity is to demonstrate innovative and practical remedial technologies at selected waste sites, a key step in proving value for widespread use and commercialization. Technologies and sites are selected primarily from the prioritized lists generated in the Volumes from Activity I, or they may be a scale-up from bench-scale experiments conducted under Activity IV.

ACTIVITY III, PROJECT 3: SULFATE-REDUCING BACTERIA DEMONSTRATION

Project Overview

Acid generation typically accompanies sulfide-related mining activities and is a widespread problem. Acid is produced chemically, through pyritic mineral oxidation, and biologically, through bacterial metabolism. This project focuses on a source-control technology that has the potential to significantly retard or prevent acid generation at affected mining sites. Biological sulfate reduction is being demonstrated at an abandoned hard-rock mine site where acid production is occurring with associated metal mobility.

Technology Description

For aqueous waste, this biological process is generally limited to the reduction of dissolved sulfate to hydrogen sulfide and the concomitant oxidation of organic nutrients to bicarbonate. The particular group of bacteria chosen for this demonstration, sulfate-reducing bacteria (SRB), require a reducing environment and cannot tolerate aerobic conditions for extended periods. These bacteria require a simple organic nutrient.

This technology has the potential to reduce the contamination of aqueous waste in three ways. First, dissolved sulfate is reduced to hydrogen sulfide through metabolic action by the SRB. Next, the hydrogen sulfide reacts with dissolved metals forming insoluble metal sulfides. Finally, the bacterial metabolism of the organic substrate produces bicarbonate, increasing the pH of the solution and limiting further metal dissolution.

At the acid-generating mine site chosen for the technology demonstration, the Lilly/Orphan Boy Mine near Elliston, Montana, the aqueous waste contained in the shaft is being treated by using the mine as an in situ reactor. A substrate composed of cow manure, wood chips, and alfalfa was added to promote growth of the organisms. This technology will also act as a source control by slowing or reversing acid production. Biological sulfate reduction is an anaerobic process that will reduce the quantity of dissolved oxygen in the mine water and increase the pH, thereby, slowing or stopping acid production.

The shaft of the Lilly/Orphan Boy Mine was developed to a depth of 250 feet and is flooded to the 74-foot level. Acid mine water historically discharged from the portal associated with this level.

Pilot-scale work at the MSE Technology Applications, Inc., Testing Facility in Butte, Montana, was performed in fiscal 1994 prior to the field demonstration. The objective of these tests was to determine how well bacterial sulfate reduction lowers the concentration of metals in mine water at the shaft temperature (8 ºC) and pH (3).

Status

During fiscal 2002, the field demonstration was again monitored on a regular basis. Figure 2 presents a cross-section of the mine and technology installation.

During the past year of monitoring, the data generally demonstrated a decrease in metals concentrations (see Figure 3), with the exception of manganese, which SRBs do not effectively remove. An increase in metals was observed during spring runoff as occurred in prior years; however, the levels decreased when flow rates returned to normal. Field demonstration monitoring has been ongoing for 8 years. Monitoring is scheduled to be completed in October 2003.

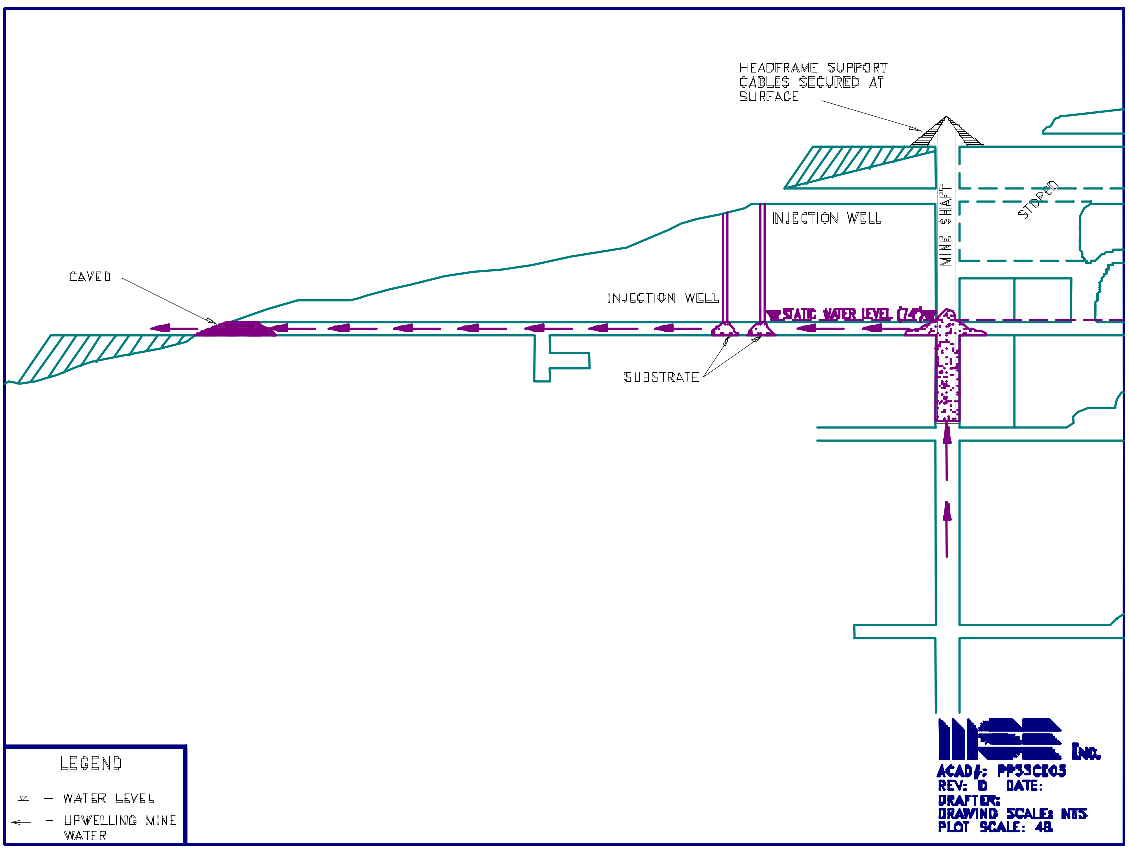

Figure 2. Cross-section of the Lilly/Orphan Boy Mine and the technology installation.

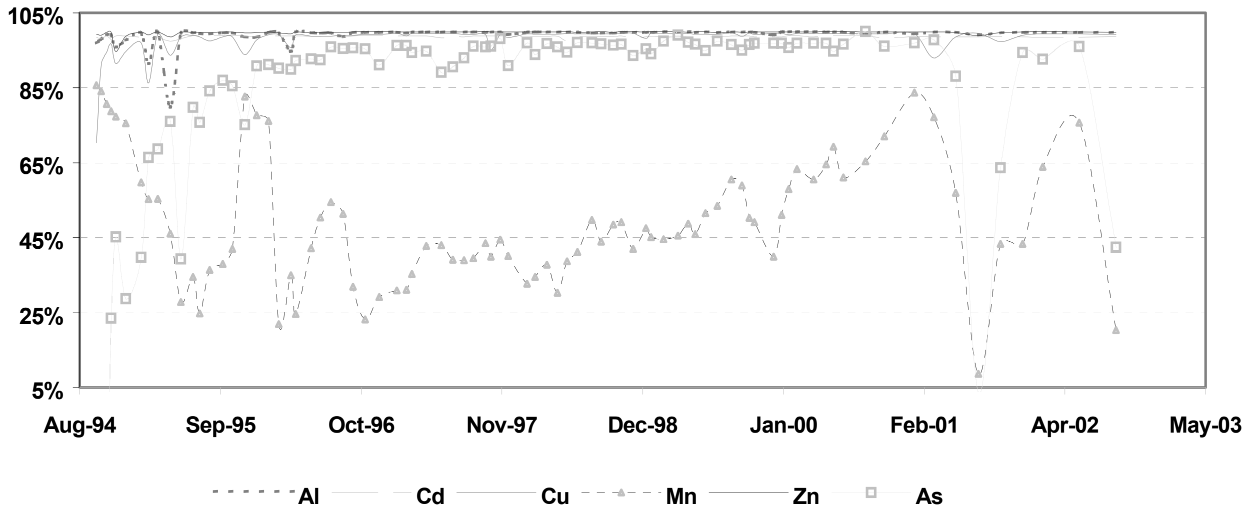

Figure 3. Metal removal efficiency at the Lilly/Orphan Boy Mine.

ACTIVITY III, PROJECT 8: UNDERGROUND MINE SOURCE CONTROL

Project Overview

A significant environmental problem at abandoned underground mines occurs when the influx of water contacts sulfide ores and forms acid and metal-laden mine discharge. The Underground Mine Source Control Project demonstrated that grout materials can be used to reduce and/or eliminate the influx of water into the underground mine system by forming an impervious barrier that results in reduced, long-term environmental impacts of the abandoned mine.

Technology Description

Groundwater flow is the movement of water through fractures, fissures, or intergranular spaces in the earth. Some of the fractures are naturally occurring; others were the result of blasting during mining.

For this demonstration, a closed-cell, expandable polyurethane grout was injected into the fracture system that intercepts the underground mine workings. The demonstration consists of three phases: 1) extensive site characterization; 2) source control material identification and testing; and 3) source control material emplacement.

Phase One, completed in 1999, consisted of characterization studies, including hydrogeological, geological, geochemical, and geophysical information gathering directly related to the mine and its operational history.

Phase Two encompassed source control material testing. Approximately 40 materials were tested according to ASTM methods for acid resistiveness, shear strength, plasticity, compressive strength, compatibility, and viscosity. The source control grout material selected for injection was Hydro Active Combi Grout, a closed-celled, expandable polyurethane grout manufactured by de neef Construction Chemicals, Inc. When compared to a cement-based source control material, this material offered the following advantages: greater retention of plasticity; less deterioration due to the acidic conditions and during rock movement; and better rheological characteristics.

Status

The Miller Mine near Townsend, Montana, was selected for the demonstration because the underground workings were accessible, it has a point-source discharge into the underground workings, the slightly acidic inflow is laden with heavy metals, and the inflow could be potentially controlled using the source control technology.

Phases One and Two were completed in March 1999. Phase Three, the field emplacement (shown in Figure 4), was completed in October 1999.

First year monitoring results indicate that the water flow into the underground mine was reduced from 10 to 15 gpm to approximately 1 to 1.2 gpm as a result of Phase III field emplacement.

In April 2000, additional grout was emplaced to reduce the flow into the mine as low as possible. The result was a reduction in flow from 1.2 to .6 gpm. Flow and water quality are being monitored until September 2003 to determine if these parameters remain the same.

Figure 4. Grout emplacement in the underground mine workings.

ACTIVITY III, PROJECT 14: BIOLOGICAL COVER DEMONSTRATION

Project Overview

Acidic, metal-laden waters draining from active and abandoned mines have had a significant environmental impact on surface and groundwater throughout the nation and the world. Specifically, the State of Montana has identified more than 20,000 abandoned mine sites, on both public and private lands, resulting in more than 1,300 miles of streams experiencing pollution problems.

Acid mine drainage arises from tailings and waste rock containing acid-generating sulfide minerals and lacking acid-consuming carbonate minerals. Sulfide minerals, such as pyrite (FeS_2), are oxidized to form sulfate, ferric iron, and acidity when exposed to oxygen and water. The ferric iron produced by this reaction contributes to further pyrite oxidation and acid generation. These abiotic oxidation reactions are greatly accelerated by the activity of acidophilic chemolithotrophic bacteria, such as *Acidithiobacillus ferrooxidans*, that inhabit mining wastes.

The key to preventing the generation of acid mine drainage is stopping the initial oxidation of pyrite. Bound with iron, the sulfur in pyrite is unable to participate in the microbially catalyzed reactions that cause acid generation. By preventing oxygen infiltration into tailings and waste rock, pyrite oxidation and subsequent acid generation can be eliminated. An innovative method to prevent oxygen transport into tailings is constructing and maintaining a biologically active cover on the surface of the tailings. This biofilm barrier is made up of microorganisms that consume dissolved oxygen from infiltrating water, thereby maintaining the reduced conditions necessary for pyrite to remain bound in mineral form.

This project involved both laboratory column studies conducted at the Center for Biofilm Engineering at Montana State University and a field test conducted at the Mammoth tailings site located near Cardwell, Montana. By conducting this demonstration, the Mine Waste Technology Program illustrated the ability of microbial biomass to remove oxygen from water infiltrating mine tailings, thereby preventing the generation of acid mine drainage. This technology promises to be an effective approach for source treatment of acid-generating mine tailings.

Technology Description

The biofilm barrier was established for this project using spray-applied nutrient treatments to the surface of the tailings to stimulate indigenous populations of oxygen-consuming bacteria. Depending on water and oxygen infiltration routes through the tailings, this technology can also be applied by subsurface injection. If appropriate populations of indigenous bacteria are not present, a bacterial inoculum can also be added with the nutrient treatments. The purpose of the nutrient solution is to supply sources of carbon and energy for microbial growth as well as sources of nitrogen, phosphorous, and necessary micronutrients. Nutrient solutions can be formulated using locally available low-cost ingredients. In this project, both molasses- and whey-based nutrient formulations were evaluated. Molasses and whey are byproducts of sugar and cheese production, respectively, and were readily available near the demonstration site. A variety of low-cost organic substrates can be used to form biofilm barriers.

The application of organic nutrient solutions stimulates the activity and growth of indigenous or applied heterotrophic bacteria within the tailings. Oxidation of organic carbon by these bacteria removes the oxygen from infiltrating water, thereby preventing the acid-generating reaction of oxygen and water with pyritic minerals within the tailings. The generation of anoxic conditions by oxygen-consuming bacteria and the presence of the nutrient solution results in the activity of fermentative bacteria, which produce conditions and substrates that promote the subsequent growth of sulfate-reducing bacteria. The activity of the latter bacterial group produces bicarbonate and sulfide, resulting in the neutralization of acid and the removal of dissolved metals as insoluble carbonate and sulfide complexes.

Status

The site selected for evaluating this technology was the Mammoth tailings site located in the South Boulder Mining District approximately 18 miles from Cardwell, Montana. Two lined test cells were constructed at the field site in the fall of 1999. An initial nutrient treatment was applied to one of the test cells (treated cell) in the fall of 1999. Additional nutrient treatments were applied to the treatment cell in the spring and summer of 2000 and 2001. The control (untreated) cell received an equivalent amount of water to that applied to the treatment cell during nutrient treatments. Other than the nutrient or water treatments, all water entering the test cells was due to natural precipitation. The test cells were not operated during the winter months when they were frozen.

The nutrient formulation used for the initial treatment and treatments applied in 2000 included molasses as a carbon and energy source, urea as a source of nitrogen, and potassium phosphate. Drainage from the treated cell had a slightly higher pH than drainage from the untreated control cell and also had significantly lower concentrations of dissolved aluminum, copper, and zinc than from the control cell. Dissolved copper concentrations in samples of the test cell effluent collected during the 2000 field season are presented in Figure 5. In contrast, to aluminum copper and zinc, the concentrations of dissolved iron and manganese were higher in samples of effluent from the treated cell relative to the control cell. These results suggest that more reduced conditions were generated in the treated cell, because at an equivalent pH iron and manganese are more soluble under reduced conditions.

In addition to lower concentrations of dissolved aluminum, copper, and zinc, effluent from the test cell treated with the molasses-based solution had significantly lower sulfate concentrations and higher populations of sulfate-reducing bacteria than the control cell effluent. These results indicate the molasses treatments stimulated the activity and growth of sulfate reducing bacteria.

Because laboratory tests conducted in the winter of 2000-2001 indicated that whey-based nutrient treatments were superior to molasses-based nutrient treatments for preventing AMD generation, whey-based nutrient solutions were applied to the treatment cell during the spring and summer of 2001. Whey is a byproduct of cheese manufacturing that contains organic carbon primarily in the form of lactose and protein. The results of the whey treatments in the field test were similar to those observed for the molasses-based treatments with a slightly higher pH and lower concentrations of dissolved aluminum, copper, and zinc in drainage from the treated cell relative to the control cell. However, there was not a discernable difference between sulfate concentrations and populations of sulfate-reducing bacteria following the whey treatments, suggesting that the molasses treatments were more effective for stimulating the activity and growth of these bacteria. Thus, the increased effectiveness of whey-based treatments over molasses-based treatments observed in the laboratory experiments were not apparent in the field test. This is likely the result of the much higher dosages of the whey in the nutrient solutions used to treat tailings in the laboratory experiments. Further research is needed to optimize the dosage rates and composition of nutrient solutions, although these parameters are likely dependant on properties of the specific tailings to be treated. Overall, the results indicate that this is a promising technology for source control of acid mine drainage.

This project has been completed and the final report is being prepared. Biofilm barrier technology for preventing acid generation by mine tailings is currently being transferred to industry through a commercial pilot-scale project at Golden Sunlight Mine.

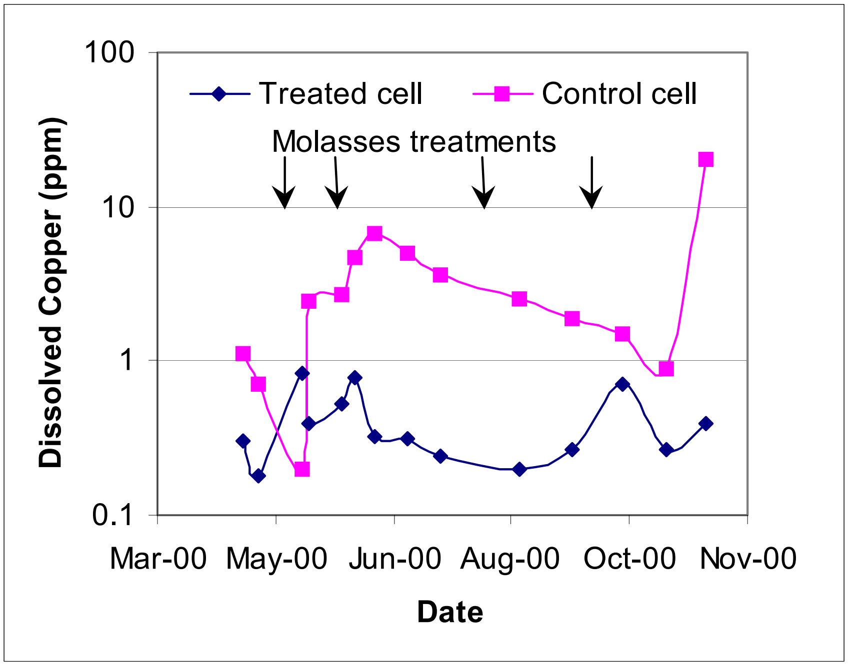

Figure 5. Dissolved copper concentrations in effluent from an untreated control cell and a test cell treated with molasses-based nutrient solution. Although effluent from the control cell often exceeded the maximum contaminant level for dissolved copper (1.3 mg/L), the treated cell remained below this level.

ACTIVITY III, PROJECT 15: TAILINGS SOURCE CONTROL

Project Overview

Processing metallic ores to extract the valuable minerals leaves remnant material behind called tailings. In the case of sulfide mineral-bearing ores, process tailings often contain large quantities of sulfide minerals that do not meet the economic criteria for extraction. These remnant sulfide minerals are usually pyrites and nonextracted ore minerals. The exposure of these minerals to air and water often leads to detrimental environmental conditions such as increased sedimentation in surface waters due to runoff events, increased wind borne particulate transport, generation of acid mine drainage, and increased metals loading in surface and groundwaters.

Technology Description

The objective of this demonstration was to identify potential source control materials and apply one or more of them at a selected site. The demonstration consists of two phases: 1) site characterization and materials testing; and 2) materials emplacement and long-term monitoring and evaluation.

Phase one consisted of the site characterization studies, including hydrogeological, geological, and geochemical information directly related to the tailings impoundment. The materials testing and development involved testing, evaluation, and formulation of source control materials for application at the selected site.

Phase two will encompass the application of three select source control materials at the demonstration site and an evaluation of the material application and feasibility. Long-term evaluation of the materials will include air borne particulate testing, moisture profiles generated from reflectometers, in situ permeability tests (using Guelph Permeameters), ex situ permeability tests, and freeze/thaw testing (flexible wall permeameter).

Status

The Mammoth Tailings site located adjacent to the historic mining town of Mammoth, Montana (see Figure 6) was the project site selected. Material testing was completed during the first quarter of 2000. Three source control materials were applied at the site during the summer of 2001. These materials included two, polymeric cementitious grouts that incorporate the tailings material as a filler material (IESCRETE and Krystal Bond) and a spray-applied, modified polyurea chemical grout. A year of volumetric soil moisture testing and material evaluation was completed by the end of calendar year 2002. The final report with the results of the monitoring and material evaluation will be finalized in the first part of calendar year 2003.

Figure 6. Mammoth Mine Tailings site.

ACTIVITY III, PROJECT 16: INTEGRATED PASSIVE BIOLOGICAL TREATMENT PROCESS DEMONSTRATION

Project Overview

The Integrated Passive Biological Treatment Process project will demonstrate a technology consisting of a series of biological processes for the complete mitigation of acid mine drainage (AMD). As the first part of this project, the technology was tested successfully at bench-scale. Now, demonstration of the process is being attempted in the field at a remote, abandoned mine, the Surething Mine, near Elliston, Montana. At this site, the bacteria live within a series of reactors constructed in the ground outside an AMD discharging mine (see Figure 7). Both anaerobic and aerobic bacteria are being used to mitigate AMD. Toxic dissolved metallic and anionic constituents are being removed, and the pH of the final process effluent is near neutral.

Technology Description

The majority of the treatment is conducted in anaerobic, sulfate-reducing bacteria (SRB) bioreactors. When provided with sulfate (present in the AMD) and a carbon source (provided in the pit reactor is a 50% cow manure and 50% walnut shell mixture), SRB produce bicarbonate and hydrogen sulfide gas. The bicarbonate neutralizes the pH of the AMD while the hydrogen sulfide gas reacts with the dissolved metal ions to precipitate them as metal sulfides.

Additional treatment is conducted in an aerobic, manganese-oxidizing bacteria (MOB), bioreactor that was designed to have an indigenous bacteria population self establish as a biofilm on the limestone cobble. Required micronutrients are to be derived from the organic matter in the water carried over from the upstream SRB Reactors.

Status

During fiscal 2002, the field demonstration was monitored regularly. The data generally demonstrated significant decreases in metals concentrations (see Figure 8) with the exception of manganese. Shortly after the system started operation, the anaerobic and aerobic reactors removed 97.8% of the influent manganese. Removal was less over the winter months. It rose again in June when 92.5% of the manganese was removed. However, the August and September manganese removals were drastically lower, indicating that a population of manganese-oxidizing bacteria may have had problems developing. The system will be watched carefully to determine if an active MOB population is developing or if any modifications to the system need to be made.

Figure 7. Integrated Passive Biological Treatment Process demonstration site.

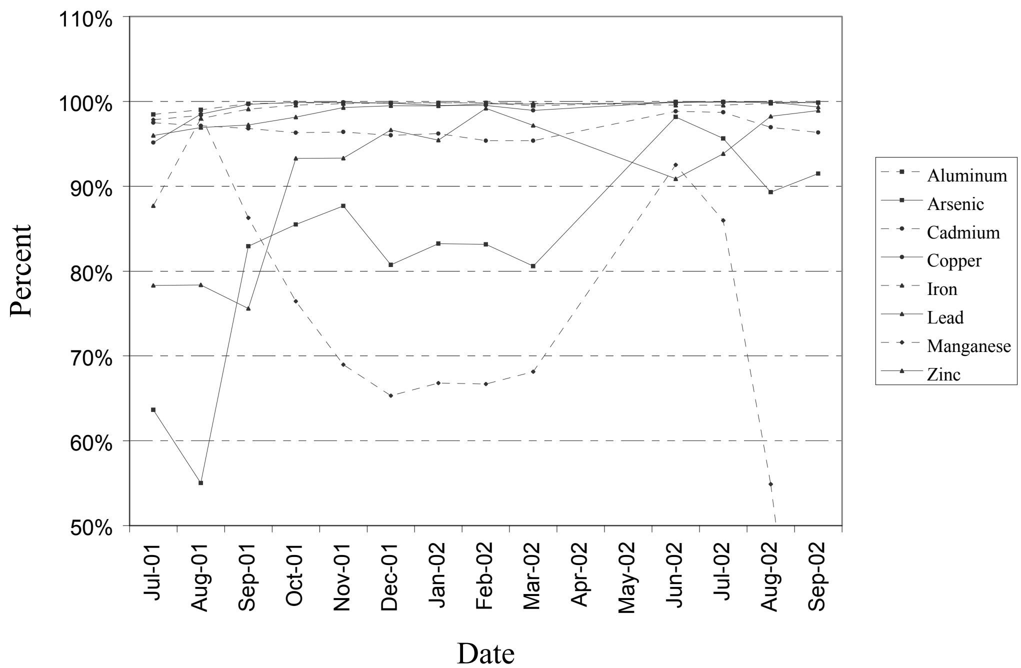

Figure 8. Metal removal efficiency for the Integrated Passive Biological System.

ACTIVITY III, PROJECT 16A: SULFATE-REDUCING BACTERIA-DRIVEN SULFIDE PRECIPITATION DEMONSTRATION PROJECT

Project Overview

Acid mine drainage (AMD), produced due to chemical and biological oxidation of sulfide minerals, consists of acidic water containing high concentrations of sulfate and dissolved metals. Pollution of ground and surface water by AMD is problematic at both active and inactive mine sites. The use of sulfate-reducing bacteria (SRB) to treat AMD is a promising alternative to conventional treatment methods. The SRB oxidize organic matter under anaerobic conditions using sulfate as a terminal electron acceptor, resulting in sulfate removal and the formation of sulfide and bicarbonate ions. The sulfide produced can react with dissolved metals in AMD, removing them from solution as insoluble metal-sulfide complexes. The alkalinity (bicarbonate) produced by SRB metabolism is capable of buffering the acidity of AMD.

Technical challenges in designing an SRB treatment system for AMD include the fact that the acidity and high metal concentrations of AMD can be inhibitory or toxic to the bacteria. Furthermore, the production of insoluble metal sulfides and hydroxides in SRB bioreactors, as well as the production of microbial biomass, can lead to plugging of the reactor systems. These challenges are being overcome in this project using a novel two-stage SRB treatment system. Bench-scale tests were conducted at the MSE Technology Applications, Inc., facility in Butte, Montana, to demonstrate the feasibility of the concept. A field-scale test system was constructed at Golden Sunlight Mine, near Whitehall Montana. This field-scale system has been very effective for increasing the pH of AMD and removing aluminum, copper, iron, zinc, and sulfate from AMD.

Technology Description

The SRB treatment system being evaluated in this project, consists of a two-stage reactor design to help separate the abiotic and biotic reactions occurring during AMD treatment. In the first stage of the process (settling pond), AMD is mixed with water containing sulfide and alkalinity generated by SRB metabolism in the second stage of the process (bioreactor). Following the abiotic buffering and metal-precipitation reactions occurring in the settling pond, the partially treated AMD enters the bioreactor. The sulfate necessary for SRB growth is provided by AMD, and organic carbon (methanol) is added to the settling pond. A portion of the treated AMD from the bioreactor effluent is recycled to the settling pond, while the remainder is discharged. This system design prevents direct exposure of the SRB to the acidic metal-laden AMD and prevents clogging of the bioreactor with metal precipitates.

Status

The field-scale system was constructed at the Golden Sunlight Mine in the summer of 2001 and began operation in the fall of 2001. The system was designed to treat drainage from the Midas dump, which is produced at rates of 1 to 3 gallons per minute. The treatment system has been very effective for buffering the influent acid mine drainage and removing dissolved metals. The water quality of the influent AMD and treated effluent water is presented in Table 2. The treatment system was very effective for removing aluminum, copper, iron, and zinc from the AMD. The mean sulfate concentration was reduced by 46%.

These data are presented as mean values ± standard deviations of measurements taken monthly from January through August 2002.

As originally scheduled, the treatment system was operated until August 2002 and then shutdown. Because the system very successfully treated AMD and project costs were less than anticipated, it was decided that the project should be extended for another year. Operation of the treatment system was resumed in December 2002 and is scheduled to operate until August 2003. An economic analysis of the treatment system is also scheduled for 2003. Overall, the results indicate that the two-stage SRB-driven sulfide precipitation system is an effective method for treating acid mine drainage.

Table 2. Water quality of influent acid mine drainage and effluent treated water from the SRB treatment system.

Parameter	Influent (mg/L)	Effluent (mg/L)
pH	2.7±0.1	6.0±0.4
Acidity	23000±10000	<10
Alkalinity	<10	1000±200
Aluminum	2750±730	2.3±1.7
Copper	122±27	0.025±0.019
Iron	440±180	11±9
Manganese	128±7	95±27
Zinc	63±8	0.10±0.08
Sulfate	28800±7730	15500±219

ACTIVITY III, PROJECT 19: SITE IN SITU MERCURY STABILIZATION TECHNOLOGIES

Project Overview

This demonstration project was conducted in conjunction with the U.S. Environmental Protection Agency's Superfund Innovative Technology Evaluation Demonstration Program. Mercury contamination often is a critical problem at mine sites, and there is a recognized need to identify technologies for mercury remediation. The application of an in situ mercury stabilization technology would provide an alternative treatment to completely removing mercury-contaminated materials from remote abandoned mine sites. As part of the overall project, MSE Technology Applications, Inc. (MSE) is responsible for conducting technology assessment activities to comparative mercury stabilization tests using mercury-contaminated material.

The Sulphur Bank Mercury Mine (SBMM) in Clear Lake, California, was chosen as the source of mercury contaminated mining wastes for this demonstration project. This abandoned mine located in a geothermal active area was historically mined for mercury and sulfur. It is now part of a 120-acre superfund site containing tailings, rock piles, and a pit lake. The mine tailings are located upgradient and extend into and along the shoreline of Clear Lake. The development of an in situ mercury treatment/stabilization technology could be used to address the significant mercury contamination problems at the site.

Technology Description

The main objective of this effort is to determine a suitable method for in situ mercury stabilization. An extensive treatability study was performed on two mercury contaminated SBMM materials by three types of stabilization technologies. The primary objective of this study was to determine the effectiveness of the three stabilization technologies (silica encapsulation, phosphate, and sulfide) in reducing the quantity of leachable mercury from SBMM material. Waste material evaluated in this study consisted of "white material" from the south white gate pile and "yellow material" from the north yellow pile. The white material was the primary test material due to its demonstrated ability to produce consistent and detectable levels of leachable mercury. The yellow material was included because it is a common material at the site, even though it yields lower levels of leachable mercury.

To evaluate the performance of the three technologies, the leachable and mobile mercury (defined as the mercury in the <25-μm filtered leachate fraction) from control columns receiving no treatment was compared to the leachable and mobile mercury in the treatment columns. Specifically, the objective was to achieve a 90% reduction in the total mass of mercury leached from each treatment relative to the control over a 12-week continuous column leaching study. The mass of mercury for each treatment and control was calculated by multiplying the mercury concentration of the <25-μm fraction collected each week by the volume of leachate collected, averaging the mass for each set of replicate treatment or control columns, and summing the total for the 12 weeks. The white material was used to evaluate the primary objective in the column study, and each treatment or control was run as triplicate columns. As a secondary objective, and with no quantitative reduction goals, the yellow material was evaluated over a 12-week period in the column tests. In addition to mercury in the leachate, the following parameters were measured: pH, redox potential, sulfate, sulfide, conductivity, alkalinity/acidity, turbidity, and other metals (arsenic, iron, and antimony).

In addition to the column tests, kinetic testing using the humidity cell procedure was run on the control white material (no treatment) and treated white material. Humidity cell testing, detailed in ASTM D 5744-96, is a protocol designed to meet kinetic testing regulatory requirements for mining wastes and ores. In this test method, the sample is subjected to alternate periods of dry air, moist air, and water leaching in an effort to simulate the weathering process that the ore would undergo in a natural environment.

Status

The predemonstration leachability studies revealed that the dominant form of leachable mercury was in a particulate and mobile form. These studies indicated that leaching with a meteoric solution released particulates that remained suspended in solution and, therefore, could be mobile in a groundwater and/or surface water hydraulic system. Levels of dissolved mercury were low in these leaching studies. A continuous column leaching test design was used to collect effluent samples over a 12-week period to evaluate leachable mercury in mobile (<25 μm) and dissolved (<0.45 μm) fractions from treated and control columns. The conventional phosphate treatment dramatically increased the levels of mobile mercury (<25 μm fraction) over the course of the 12-week study. A 94.7% increase in the total mass of mercury leached occurred relative to the control. Sulfide treatment did not appear to be effective in reducing the levels of mobile mercury in the column tests. There was no significant difference in the cumulative levels of mobile mercury in the effluent from the sulfide treatment relative to the control. Silica microencapsulation was effective in reducing mobile mercury (<25 μm) very close to the 90% reduction goal of the study. However, the dissolved mercury portion (<0.45 μm) of the mobile fraction increased by approximately 200% relative to the control.

ACTIVITY III, PROJECT 21: INTEGRATED PROCESS FOR TREATMENT OF BERKELEY PIT WATER

Project Overview

The objective of this project is to develop integrated, optimized treatment systems for processing Berkeley Pit water. The Berkeley Pit is an inactive open-pit copper mine located in Butte, Montana. Currently containing approximately 37 billion gallons of acidic, metals-laden water, the Berkeley Pit is filling at a rate of approximately 3 million gallons per day and is a good example of acid rock drainage.

Two optimized flowsheets will be developed. One flowsheet is to be oriented toward minimizing the overall cost of water treatment to meet discharge requirements; this will include not only water treatment equipment but also sludge handling/management. The other flowsheet is to be oriented toward also meeting discharge requirements, but includes the recovery of products from the water (e.g., copper, metal sulfates, etc.) to potentially offset treatment costs and result in overall better economics.

Technology Description

The project will evaluate proven technologies (e.g., precipitation, ion exchange, cementation, solvent extraction, electrolysis, filtration options, etc.) as well as technologies with credible pilot-scale supporting data. Technologies with only laboratory testing history will not be included. The goal is to assemble the sequence of unit operations resulting in the most attractive overall economics.

Status

In FY02, work progressed on the project final report, focused primarily on the water treatment flowsheet. Results indicate that discharge of sludge from treatment to the Berkeley Pit, using a high-density sludge lime treatment process, is the most economically favorable approach. Efforts expended on metals recovery indicate that most of the metals present cannot be profitably recovered due to their low value and dilute concentrations. Copper can be recovered profitably using the existing cementation process, recovery as a sulfide, or electrolytically by the EMEW cell technology. Upgrading the sulfide to a sulfate or oxide may improve the economics of that option. It appears that no other metals are economically recoverable. If zinc can be cheaply upgraded to a form other than sulfide, it may also be economically recoverable, but probably not at current zinc prices. Fiscal 2003 plans include completing the project final report.

ACTIVITY III, PROJECT 22: PHOSPHATE STABILIZATION OF MINE WASTE CONTAMINATED SOILS

Project Overview

The project goal is to provide information to support technical feasibility and regulatory acceptance of phosphoric acid-based in situ stabilization of lead in residential soils at the Joplin, Missouri National Priorities List Site. The ultimate goal is to demonstrate this technique is a cost-effective alternative to excavation and haulage of metal-contaminated soils to a waste repository.

Technology Description

The remediation approach involves mixing commercial grade phosphoric acid and a trace of potassium chloride into near surface soils, followed by pH adjustment (e.g., with lime addition) to attain paraneutrality. As a result, soluble lead is converted to pyromorphite, a highly insoluble and environmentally stable mineral. Subsequently, lead uptake from rooting zone soils (into aboveground plant biomass) and into the bloodstream of young children (from the gastrointestinal tract) is significantly reduced.

Status

Sampling and analysis of soil and plant materials collected from the field test plot; dosing of young swine with soils from the test plot; and laboratory characterization of the treated soils were completed in FY02. The results for the swine dosing, bioaccessibility, and plant (metals) uptake studies are presented and discussed in the draft final report for this project. Overall, addition of one percent by weight phosphoric acid appears to reduce the environmental mobility/availability of lead to about one-half that observed in untreated soils. This document was submitted for internal review at the end of FY02.

ACTIVITY III, PROJECT 23: REVEGETATION OF MINING WASTE USING ORGANIC AMENDMENTS AND EVALUATE THE POTENTIAL FOR CREATING ATTRACTIVE NUISANCES FOR WILDLIFE

Project Overview

The objectives of this project are to demonstrate the use of organic amendments to enhance the establishment and growth of grass on lead mine tailings and to evaluate the affect of those amendments on plant uptake of metals. Two sources of compost and an organic fertilizer derived from municipal sewage treatment plant sludge were incorporated into two types of tailings near Desloge, Missouri, and the replicated plots were planted with grass. Both types of tailings (fine-textured floatation tailings and course-textured gravity separation tailings referred to as chat tailings) contain elevated concentrations of lead, zinc, and cadmium. This project will be evaluated for three growing seasons.

Thousands of abandoned mine and mineral processing sites throughout the United States are very unattractive and can be a significant environmental hazard. The federal government and responsible parties need to develop cost-effective remedial approaches to effectively manage these large areas that are contaminated with a wide variety of metals. Natural revegetation is often prevented in these areas because of low pH, phytotoxic concentrations of metals, poor physical structure for plant growth, nutrient deficiencies, and slopes too steep for plant establishment. Mine waste reclamation research frequently includes the addition of organic soil amendments, since mine waste materials are typically subsurface in origin and have minimal organic content. However, the diversity of organic amendments used and the lack of uniformity within each category of material make comparisons among sites and studies difficult. In addition, while it is generally agreed that organic amendments are capable of stabilizing mine waste metals, the potential for post reclamation impacts to wildlife due to plant uptake of those metals requires further research.

Technology Description

MSE Technology Applications, Inc., established field plots at the Big River Mine Tailings Site and the Leadwood Chat Tailings Site in Missouri in the spring of 2000. The plots were evaluated to determine vegetation establishment, biomass production, and plant uptake of metals. Procedures for establishing, maintaining, and evaluating the plots will be broadly applicable and reproducible so that subsequent studies at other locations will produce comparable information. The three organic amendments are milorganite, ormiorganics compost, and St. Peters compost. These amendments were applied at a low, medium, and high application rate. Each amendment/application rate combination was replicated four times including a control plot that only received the inorganic fertilizer at both sites, totaling 80 plots. The plant species for the demonstration was tall fescue (Kentucky variety). The plots were monitored monthly from May through September 2000. The project will be evaluated for three growing seasons.

Status

The following figures show the Big River mine Tailings plots over 3 years. Figure 9 shows the Big River Mine Tailings site after planting. Figure 10 shows the plots after 6 months of growth. Figure 11 shows the plots after second growing season and Figure 12 after third growing season.

For the three years (2000-2002), the average concentrations for each of the ten treatments including the unamended but fertilized control plots were evaluated for three quantitative objectives: maximizing vegetative cover and production while minimizing the transfer of contaminants from rooting zone soils into aboveground biomass; duration of effectiveness; and preliminary cost estimates for reclamation. In general, both the Milorganite and control treatments did not meet the criteria, however, the St. Peters compost and ormiorganic treatments generally met the criteria. In comparison, the treated compost plots demonstrate the benefits of amending with some form of organic matter. Also, increasing the rate of addition of these amendments appears to increase both cover and biomass production.

In summary, compost has been effective in establishing vegetative cover at both sites. Additional results for 2002 will be discussed in a Final Report to be issued July 2003, including a cost analysis.

Figure 9. Big River Mine Tailings Site after planting (April 2000).

Figure 10. Big River Mine Tailings Site after first season (September 2000).

Figure 11. Big River Mine Tailings Site after second season (September 2001).

Figure 12. Big River Mine Tailings Site after third season (September 2002).

ACTIVITY III, PROJECT 24 IMPROVEMENTS IN ENGINEERED BIOREMEDIATION OF ACID MINE DRAINAGE

Project Overview

Acid mine drainage (AMD) emanates from many abandoned mine sites in the western United States. Such drainage, having an elevated content of dissolved metals and low pH, presents an environmental problem that needs to be economically addressed. Sulfate-reducing bacteria (SRB) have the ability to immobilize dissolved metals, by precipitating them as sulfides, and increase pH provided that a favorable biochemical environment is created. Such conditions may be created by constructing artificial wetlands, if space is not limited, or converging the AMD flow to an engineered passive SRB reactor.

A SRB reactor contains an organic-carbon chamber that is vital for its operation. A life span of a properly designed reactor depends on the organic carbon supply, permeability of organic-carbon chamber, and the capacity of the reactor to accumulate precipitated sulfides.

When the source of organic carbon is depleted, or becomes unavailable, because permeability of the organic matter decreased due to settling processes or physical or chemical encapsulation, the bioreactor will cease operating. To reactivate such a bioreactor, the organic carbon source has to be replenished. Therefore, it is desirable to: 1) maximize the time interval between such operations; and/or 2) be able to predict the longevity of the carbon source to economically optimize the reactor's size.

Similarly, when the capacity of the bioreactor's chamber that was designed to hold precipitated sulfides is exhausted, the sulfides will either break through or the reactor will plug ceasing its operation. This project addresses engineering improvements that include replacing the organic carbon supply-system in a SRB reactor and refining how the reactor is sized.

Technology Description

Engineered improvements of SRB reactors are to be accomplished by implementing the four tasks listed below.

Task I–Selecting Optimal Media with Organic Carbon

The optimal media needs to: 1) contain a sufficient amount of organic carbon; 2) be used economically as passive SRB bioreactors; and 3) have high potential to be permeable when saturated with water. Determination of the optimal organic carbon media will be done through a literature study. A database was set up that included the media technical parameters, records of use, availability, price index, etc.

Task II–Designing a Permeability and Contact Time Enhancing System (PACTES)

PACTES will ensure a good supply of organic carbon and will maintain good permeability of the organic matter throughout the predicted life of the reactor.

Task III–Designing an Organic Carbon Replaceable Cartridge System (RCS)

A replaceable cartridge system will be easy to install and replace in a bioreactor, particularly at a remote location.

To ensure that PACTES and RCS systems are compatible, their development was symbiotic. Work on each system included the following phases: 1) developing a list of concepts for each system; 2) narrowing the list to the most (one) applicable solution; 3) laboratory testing of the selected solution; 4) preparing the design document; 5) constructing the prototype of the RCS combined with PACTES; and 6) bench-test study of the constructed prototype.

Task IV–Developing a Computer Software to Simulate SRB Activities in the Bioreactor

The software will enable a designer to efficiently design and size a bioreactor by quantifying the expected rate of organic carbon depletion and the volume of SRB activity by-products.

Status

Task I was completed, and a report of the findings entitled *Evaluation of Organic Substrates for the Growth of Sulfate-Reduction Bacteria to Treat Acid Mine Drainage* was prepared. The report contained the Microsoft Access database that included information obtained from more than 90 publications that identified 36 organic substrates; among them, 7 substances were direct, e.g. methanol, lactate, etc., and 29 were indirect, e.g. manure, sludge, wood waste, etc.

The following conclusions were reached upon completing this task.

- Selecting an organic substrate should be based on effectiveness, cost, and availability.

- A mixture of substrates, with varying degrees of biodegradability, provides the best long-term bioreactor performance.

- Directly utilizable SRB substrates (i.e., methanol or lactate) can be used to either initiate the SRB activity or restore the activity to spent organic media.

- The suitability of a substrate mixture for treating a particular AMD is best assessed empirically using laboratory tests.

As a result of the investigation conducted for Task I, a mixture of walnut shells and cow manure was selected as the optimum organic medium for the project. Cow manure is readily biodegradable, and the slow biodegradable walnut shells enhance long-term performance of the bioreactors and provide a structure for the organic medium to prevent it from settling.

Task II, development of PACTES, was completed. The PACTES consisted of a mixture of walnut shells and manure (organic medium) prepacked in plastic-net bags, approximately 5 gallons in volume. The mix consisted of 50% manure and 50% walnut shells by volume.

Task III was advanced to developing the design for the RCS that includes an 8-foot- diameter, 7-foot-tall plastic tank with two vertical columns that serve as the AMD distribution system and a discharge pipe, respectively. These columns may also be used as cleanup ports, if needed. Acid mine drainage flows horizontally from the distribution system to the discharge pipe passing through organic medium bags that fill the tank see Figure 13.

Initial work on Task IV identified an existing software, MINTEQAK, that was developed to simulate biochemical processes occurring in wetlands. This software must be modified to enable input of variables for the time and spatial coordinates.

Work on the project will continue into the end of fiscal 2003.

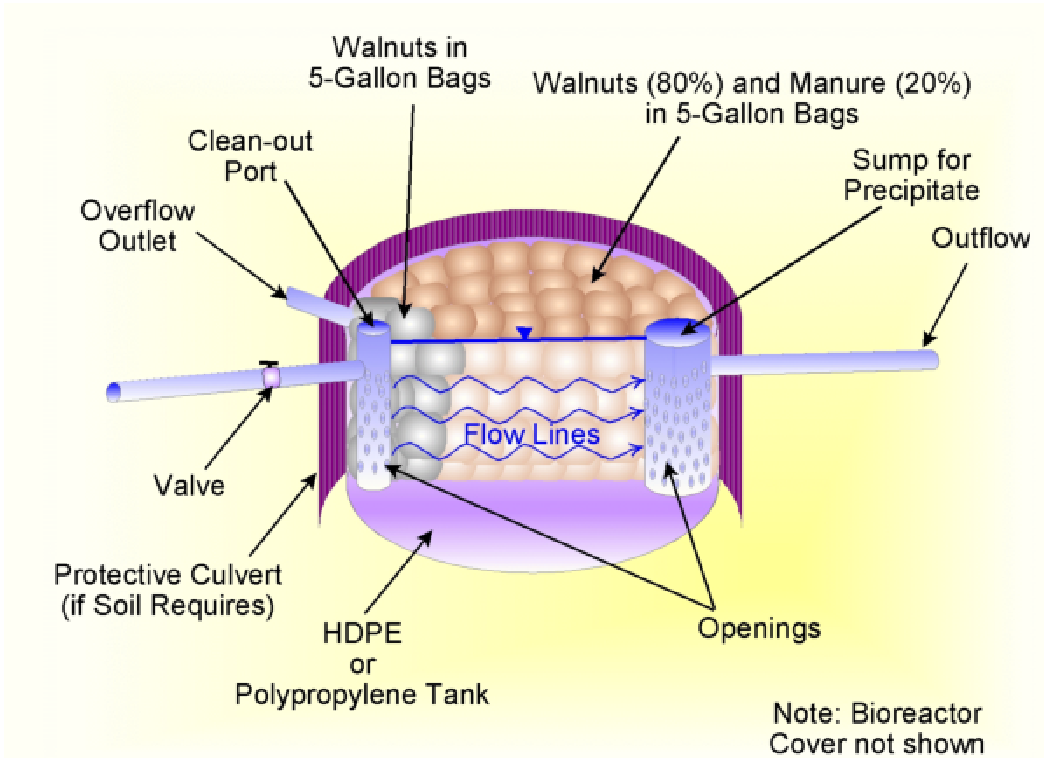

Figure 13. Sulfate-reducing bacteria replaceable cartridge system

ACTIVITY III, PROJECT 25 PASSIVE ARSENIC REMOVAL DEMONSTRATION PROJECT

Project Overview

The purpose of this demonstration was to evaluate, at bench scale, innovative passive arsenic removal technologies that have applicability to remote mine sites with a focus on materials that could be placed in passive gravity-feed bed reactors. The abilities of several technologies to passively remove arsenic and to potentially alleviate environmental problems associated with acidic, metal-laden mine drainage was demonstrated.

A main objective of this project was to develop information about selected innovative, passive arsenic removal technologies that would be applicable to remote mine site locations. The technical objectives included demonstrating that a significant removal of arsenic could be achieved and comparing the capabilities of each technology.

After evaluating several mine waters and considering project budget constraints, it was decided to conduct testing with water from only one source and to use typical high arsenic acid mine drainage (AMD). Water from the Susie/Valley Forge Mine in Rimini, Montana, was selected for the bench-scale test work. The average pH of the water used for this demonstration was 3.1. Typical metal concentrations ranged from 0.2 to 3 milligrams per liter (mg/L) arsenic and 9.3 to 100 mg/L iron. Most of the iron was present as ferric and most of the arsenic was present as arsenate.

Technology Description

This project was a laboratory evaluation of several passive technologies capable of removing arsenic from mine drainage. The most effective conventional arsenic treatment technology is arsenic adsorption/precipitation with ferric or magnesium hydroxide. However, the pumping and mixing equipment required for this chemical precipitation method makes it difficult to adapt to remote locations. Consequently, this project was focused on identifying technologies that would be capable of passively removing arsenic from mine drainage. In the project literature search phase, several media were identified.

The media selected for laboratory column testing were chosen for their ability to operate in a fixed bed reactor and consisted of manganese-dioxide-coated sand (Greensand), granular activated alumina, granular ferric hydroxide, iron filings, limestone, apatite, granular sulfide, and granular activated carbon. Silica sand was selected as the control media.

For the demonstration, the arsenic removal media were placed in 2-by-18-inch columns (see Figure 14). The arsenic-contaminated mine water was pumped upward through the columns at a rate to average a 30-minute retention time in all columns. One control column was used, and only one column was used to test each media.

Status

Through 500 pour volumes of arsenic contaminated water, most of the test media showed an arsenic removal of 100%. The exceptions were apatite with a removal rate of only 97.5%, activated carbon with a removal efficiency of 99.4%, and limestone with a removal rate of 99.7%. The project proceeded according to the approved Quality Assurance Project Plan through 1,500 pour volumes. However, since notable high arsenic removal trends were still evident for all the media, the project was discontinued due to lack of column breakthrough. The percent arsenic removal for each media at the measured pour volumes is shown in Table 3.

In this laboratory investigation of passive removal of arsenic through bed media, most of the overall efficiencies were highly encouraging. Since water with a high iron to arsenic ratio was tested, some of the arsenic removal may have resulted from ferric hydride/arsenic coprecipitation. However, as most AMD from hardrock mining operations exhibit high concentrations of dissolved iron, the results of this project will serve to provide applicable information for using these tested media in a passive arsenic treatment system.

Before a field demonstration is conducted, a better evaluation of the specific arsenic removal mechanisms for each of the tested media should be conducted. It is recommended that water with a much lower iron to arsenic ratio be tested. This would allow the column materials to be more fully evaluated as to their ability to remove arsenic by decreasing the competition from iron-arsenic coprecipitation.

Table 3 . Results of laboratory column testing with passive arsenic treatment media.

Pour Volumes	Magnesium Dioxide	Ferric Hydroxide	Activated Alumina	Limestone	Silica Sand	Sulfide	Iron	Activated Carbon	Apatite
0	99.0%	99.5%	99.5%	98.9%	99.5%	99.7%	99.5%	99.1%	50.9%
40	99.4%	99.7%	99.7%	99.5%	99.7%	99.7%	99.5%	99.7%	98.1%
100	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%	96.7%
300	99.5%	100.0%	99.7%	100.0%	100.0%	100.0%	100.0%	99.2%	97.9%
500	100.0%	100.0%	100.0%	99.7%	100.0%	100.0%	100.0%	99.4%	97.5%
700	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	96.5%
900	99.2%	99.2%	99.2%	99.0%	99.2%	99.2%	99.2%	99.2%	98.7%
1,100	99.4%	99.7%	100.0%	99.5%	100.0%	100.0%	100.0%	99.7%	99.5%
1,300	99.7%	99.5%	99.5%	99.7%	100.0%	100.0%	100.0%	100.0%	100.0%
1,500	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%

Figure 14. Laboratory column testing of media at the MSE Testing Facility in Butte, Montana.

ACTIVITY III, PROJECT 26 PREVENTION OF ACID MINE DRAINAGE GENERATION FROM OPEN-PIT MINE HIGHWALLS

Project Overview

Exposed, open-pit mine highwalls contribute significantly to the production of acid mine drainage (AMD) and can be problematic upon closure of an operating mine. Four innovative technologies were evaluated under the Mine Waste Technology (MWTP), *Prevention of AMD Generation from Open-Pit Highwalls Demonstration Project*. The objective of the field demonstration was to evaluate technologies for their ability to decrease or eliminate acid generation from treated areas of the highwall, compared to untreated highwall areas.

Technology Description

Generation of AMD from open-pit mine highwalls has been addressed in a limited manner, and little information is available on the subject. Most likely, this is due to the difficulty and danger of physically working on or near the face of the highwall. Other areas of concern such as mine tailings, underground workings and other above ground waste rock piles can usually be dealt with by physical means to control the generation of AMD, i.e., removal or application of a permanent impermeable cover. However, highwall generated AMD will continue to be produced for indefinite periods of time as weathering occurs and the flushing action of atmospheric precipitation and/or groundwater infiltration through the highwall takes place.

The main purpose of this project is to research technologies applicable to controlling or eliminating AMD generated from open-pit mine highwalls and then apply and monitor the potential technologies under actual field conditions. For this demonstration, four technologies having potential to passivate the AMD from a highwall were selected. The application methods required to apply each technology varied along with the application time and the materials.

The demonstration consists of three phases: 1) extensive site characterization and gathering background information; 2) technology identification and field application; and 3) long-term field monitoring and laboratory testing for confirmation of field results.

Site characterization in Phase I included core drilling the highwall to determine geology, hydrogeology, and extent and depth of acid generation (i.e. geochemical analysis), and performing background sampling at all of the sampling ports placed on the highwall. Phase II involved selecting the application for the highwall technologies at Golden Sunlight Mine (GSM).

The third phase of the project involves monitoring the technologies using ASTMD 5744-96, Accelerated Weathering of Solid Materials using a Modified Humidity Cells, residual wall rinse samples from the treated highwall plots, microscopy, and other methods.

Status

The field demonstration was performed at GSM, a subsidiary of Placer Dome, an operating gold mine located near Whitehall, Montana. The ore body at GSM is sulfidic, and the exposed highwall provides an AMD source.

Phase one, site characterization, was completed in September 2001.

Phase two, included selecting four technologies, was completed by May 2001. Placement of the technologies was performed between October and December 2001.

The technologies were evaluated in 2002 using a residual wall rinse sampling method and a modified humidity cell testing method. Because of the inherent problems with the residual rinse sampling method (i.e., earth movement, erosion, and air borne particulate accumulation) humidity cell testing was begun as a backup evaluation method. The humidity cell testing was extended for 41 weeks and is scheduled to be completed in FY03.

ACTIVITY III, PROJECT 29 REMEDIATION TECHNOLOGY EVALUATION AT THE GILT EDGE MINE

Project Overview

The objective of this project is to generate performance and cost data for promising new technologies for preventing the oxidation of sulfide waste rock, which may be applicable to many mine waste sites. The new technologies will be compared to the presumptive remedy of lime treatment as well as to controls in which no treatment is performed. The technology demonstration will be performed at the Gilt

Edge Mine, a 270-acre, open-pit cyanide heap leach gold mine located about 5 miles southeast of Lead, South Dakota. The immediate area was the site of sporadic mining activity for over 100 years. The Gilt Edge Mine was operated by Brohm Mining Corporation, a wholly owned subsidiary of Dakota Mining Cooperation from February 1986 until July 1999. Brohm's activities included developing several open pits, crushing and placing the ore on a heap leach pad for gold leaching by cyanidation, and Merrill-Crowe gold recovery in an on-site mill. In July 1999, the mine's owners (Dakota Mining Corporation) declared bankruptcy, resulting in the Gilt Edge site being returned to the State of South Dakota for management. After incurring significant costs for water treatment to ensure no discharge of acidic mine water to the environment occurred, the State of South Dakota requested that EPA Region VIII take over the site and list it on the National Priorities List (NPL) as a Superfund site. The Gilt Edge Mine site presents an opportunity to evaluate emerging acid mine drainage (AMD)-treatment technologies while gathering data leading to a Record of Decision (ROD) for the site.

This project is a collaboration between EPA Region VIII and the EPA Mine Waste Technology Program (MWTP). The objective of Region VIII is to conduct a treatability study as part of the remedial investigation/feasibility study process for the site—providing data to help make decisions supporting the ROD for the site. The technical and economic information will be summarized in a final report.

The project involves constructing test cells, which will be loaded with sulfide-bearing waste rock from the Gilt Edge Mine site. EPA Region VIII (or its contractors), assisted by the U.S. Bureau of Reclamation will design and construct the test cells, as well as load the waste rock. Three technology providers will each install its respective technology for reducing AMD generated by the waste rock. The project will take place west of the Anchor Hill Pit at the Gilt Edge Mine. The test cells will receive ambient precipitation, and an irrigation system will apply additional simulated precipitation to the test cells. A system for managing and sampling leachate quality designed by EPA Region VIII will be integrated into the cell design. Twelve test cells are planned. Two cells are dedicated to each of the three technologies to show performance repeatability. Three control cells containing only waste rock (with no additional treatment) and three cells representing the presumptive remedy of blending lime with the waste rock will also be constructed. The performance of the installed technologies will be judged primarily by comparing leachate water quality from the installed technology cells with that of the control and presumptive remedy (lime treatment) cells. The test cells will be constructed and loaded in September 2000. EPA Region VIII will monitor for 1 year; thereafter, the monitoring responsibility will be transferred to MWTP, while EPA Region VIII uses the generated data in preparing the site ROD. Monitoring will continue for at least 1 additional year, with following years added if budget allows and if observed results make it advisable to do so.

Technology Description

The three technologies to be demonstrated are:

- Silica microencapsulation [Klean Earth Environmental Company (KEECO)];
- Envirobond [Metals Treatment Technologies (MTT)]; and
- Passivation technology [Mackay School of Mines, University of Nevada, Reno (UNR)]

KEECO has developed a treatment technology for treating and preventing metals-contaminated waters, soils, and possibly sulfidic waste rock called silica microencapsulation (SME). This technology encapsulates metals in an impervious microscopic silica matrix (essentially locking them up in very small sand-like particles) that prevents the metals from leaching and migrating. Its chemical components react when introduced to water, creating an initial pH adjustment and electrokinetic reaction. The electrokinetic reaction serves to facilitate electrokinetic transport of metal particles toward the reactive components of the SME product, enhancing its efficiency. Metal hydroxyl formation follows; next, silica encapsulation of the metals occurs, forming a dense, stable coating. Contrary to conventional treatment process where sludges typically degrade over time, the SME silica matrix appears to continue to strengthen and tighten, providing for long-term isolation of contaminants from the environment. Silica microencapsulation has been applied to wastewater, sediment, sludge, soil, mine tailings, and other complex media but has never been applied and tested directly on sulfidic mine waste rock materials.

The Envirobond (Metals Treatment Technologies) technology is similar to the KEECO technology except that it involves phosphate stabilization chemistry rather than silicates. The technology has been applied at mining sites, firing ranges, sediment removal sites, and others to produce a solid treatment material meeting Toxicity Characteristic Leaching Procedure criteria. The technology can be adapted for a variety of wastestreams and soil conditions.

Over the past few years, DuPont developed a novel coating method known as a passivation technology. Recently, the technology was donated to UNR for further development and commercialization. The passivation process essentially creates an inert layer on the sulfide phase by contacting the sulfide with a basic permanganate solution to produce an inert manganese-iron oxide layer. This layer prevents contact with atmospheric oxygen during weathering of the sulfide rock, thus, preventing sulfuric acid generation. Another critical element of the process is the addition of trace amounts of magnesium oxide during pH adjustment. Magnesium oxide addition enhances the coating strength.

Status

The treatment cells were loaded and treated by the technology vendors in November 2000. Treatment monitoring started May 2001 and has continued through the fall of 2002. Monitoring was suspended during the winters due to the cells freezing.

Treatment data indicates all the treatments initially increased the pH of the water infiltrating through the waste rock as shown in Figure 15. However, during the summer of 2002, effluent from the KEECO cells decreased to the control cell's levels.

The total dissolved solids (TDS) data (Figure 16) shows that the presumptive remedy (lime treatment), UNR Passivation treatment, and KEECO SME treatment did initially reduce the TDS concentration significantly; whereas, the MT^2 treatment initially increased the TDS concentration when compared to the control cells. This is due to the fact the MT^2 treatment liberated the arsenic (Figure 17) in the waste rock and was dissolved into the infiltrating water. During the summer of 2002, the MT^2 TDS concentrations decreased, whereas, the KEECO TDS concentrations began to increase, while the TDS levels for the UNR and presumptive treatments remained well below the control levels.

The data through 2002 shows that the presumptive treatment and the UNR Passivation treatment significantly reduced the concentration of metals and raised the pH of the infiltrating water when compared to the control cells. The high TDS and arsenic concentration of the MT^2 treatment causes concern and will need to be addressed if the treatment is used as a remediation of waste rock. The decrease of pH and increase of the TDS concentration for the KEECO SME treatment indicates the treatment may have worked initially, but it is starting to degrade and will fail.

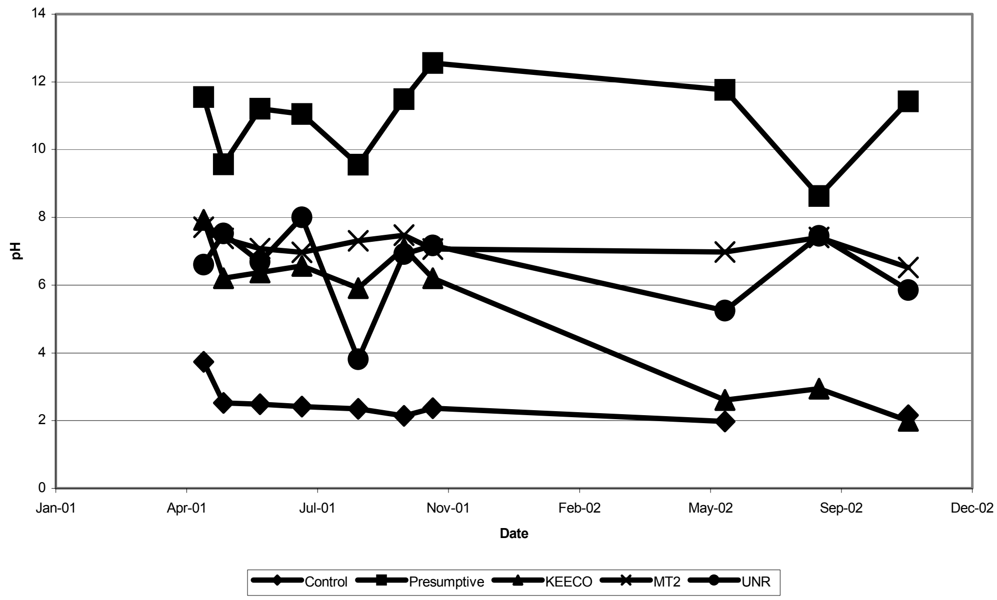

Figure 15. Gillt Edge pH trends.

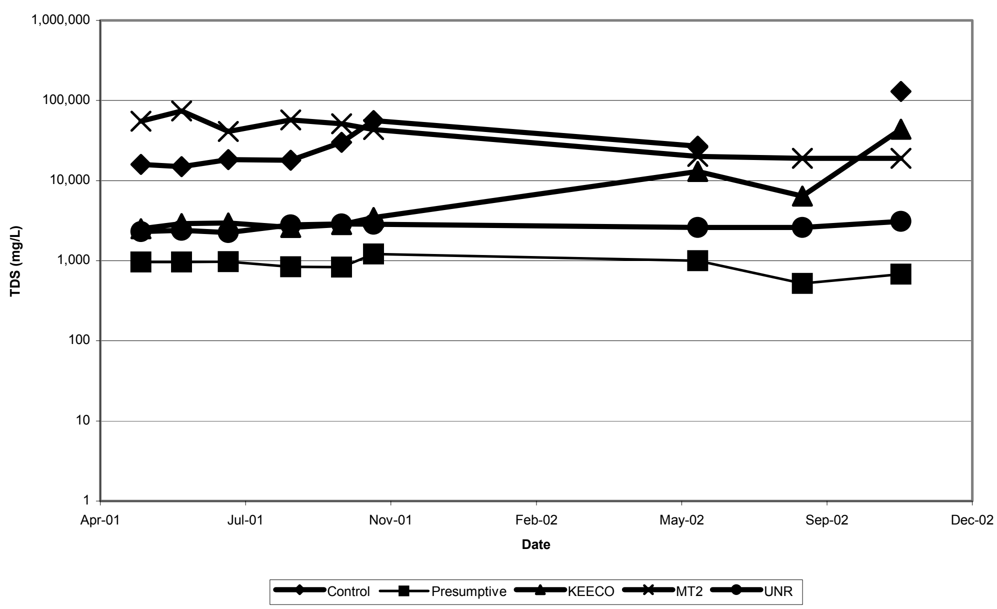

Figure 16. Gilt Edge total dissolved solids trend.

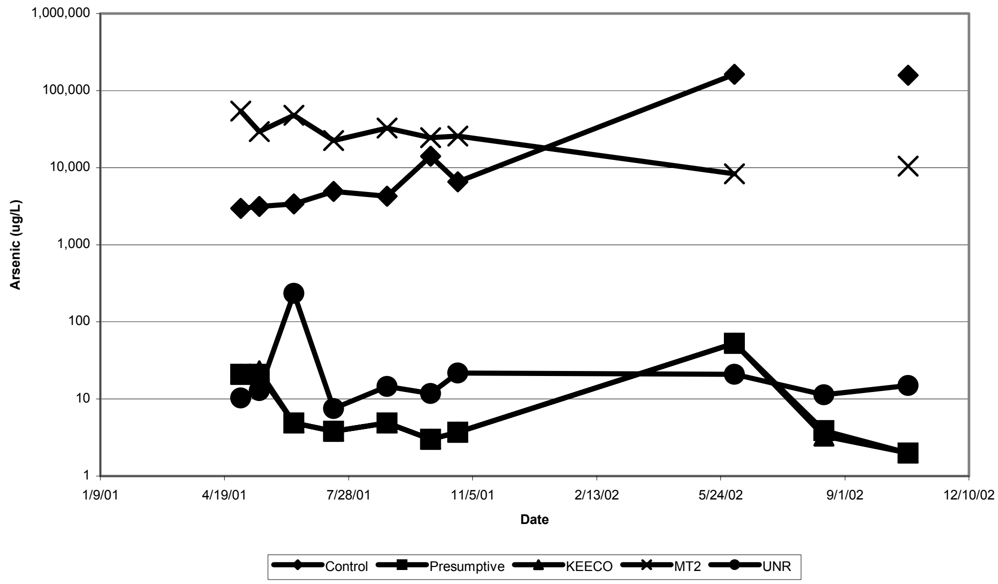

Figure 17. Gilt Edge arsenic trends.

ACTIVITY III, PROJECT 30 ACIDIC/HEAVY METAL-TOLERANT PLANT CULTIVARS DEMONSTRATION, ANACONDA SMELTER SUPERFUND SITE

Project Overview

Presently, grass, forb, and shrub species commercially available for reclaiming acidic/heavy metals-contaminated (A/M) soils often come from outside the Northern Rocky Mountain region. These cultivated varieties may not tolerate the climatic-edaphic stresses (in addition to A/M stresses) as well as would A/M ecotypes indigenous to the region. Over the past several years, plant populations exhibiting A/M tolerance potential have been collected from the Anaconda Smelter Superfund Site and evaluated in laboratory, greenhouse, and preliminary field trial studies. The results indicate that self-sustaining plant communities comprised of native A/M tolerant ecotypes are possible. Thus, the goal of this project is to formally compare the performance of local seed mixes against comparable mixes now commercially available. If the local ecotypes (of the given grass/forb species) are indeed best performing, they would be made available for full-scale reclamation of hardrock mine/mill/smelter sites in the region.

Technology Description

The team comprised of the Deer Lodge Valley Conservation District (DLVCD), USDA/Bridger Plant Materials Center (BPMC), and MSE Technology Applications, Inc., will select and evaluate the most promising grass/forb accessions at test sites in the Anaconda area over the 2002–2004 growing seasons. Shrub species will be evaluated at another site that is not formally part of the Mine Waste Technology Program funded study. Four grass/forb mixtures from southwestern Montana were compared against four very similar mixtures of commercially available cultivars. Four replications of each mixture were used at both the upland (Stucky Ridge) and lowland (Mill Creek) test sites. The laboratory and field data gathered during the three seasons will be statistically analyzed to determine whether any of the local seed mixes outperforms their commercial counterparts.

Status

The following activities continued in FY02: collection and laboratory analysis of plant and soil samples from the Anaconda area; greenhouse and field evaluations of plant performance; and production of seeds (at BPMC) from the most promising grass/forb accessions. The two test sites were planted, and baseline soil samples were collected for target heavy metals levels analysis. The laboratory results (in Table 4) indicate the general suitability of these sites as a test bed for this project.

All eight seed mixtures performed well at the BPMC control facility. However, no growth was observed for any of the mixtures planted at the two test sites at Anaconda. We suggest that a combination of drought and soil contaminant stress precluded effective seeding growth and stand establishment. Subsequently, the project team began working with personnel from the regulatory agencies and Montana State University's Restoration Research Unit to revise methods for establishing vegetation growth at the Anaconda sites. The agencies agreed to pretreatment of the soils, i.e., liming and fertilizing, and to comparison of accessions within a species versus performance of the given seed mixtures. These new approaches will be implemented in the fall and early spring of FY03.

Table 4. Development of Acid/Metal Tolerant Cultivars Project: Baseline Soils Data Summary[a].

A. Upland/Stucky Ridge Plot

	As	Cd	Cu	Pb	Zn	pH / Eh
DLVCD-BPMC	131	2	$\boxed{502}$	44	133	$\boxed{5.5}$ / 380
MSE	$\boxed{178}$	1.8	$\boxed{779}$	66	161	$\boxed{4.7}$ / 302

B. Lowland/Mill Creek Plot

	As	Cd	Cu	Pb	Zn	pH / Eh
DLVCD-BPMC	$\boxed{386}$	$\boxed{8}$	$\boxed{676}$	174	$\boxed{464}$	6.2 / 323
MSE	$\boxed{493}$	$\boxed{10}$	$\boxed{858}$	212	$\boxed{650}$	5.8 / 262

Notes: [a] Acid-extractable metals in mg/kg; pH in S.U. and Eh in mv
[b] $\boxed{}$ values are ≥ threshold of concern levels, from QAPP; level for Pb is > 400 mg/kg

ACTIVITY III, PROJECT 33 MICROENCAPSULATION TO PREVENT ACID MINE DRAINAGE

Project Overview

This technology demonstration project is being conducted on a cost share basis with the Minnesota Department of Natural Resources. The objectives are to evaluate the potential field application success in preventing acid mine drainage and to estimate requirements for field applications.

An unoxidized sulfidic rock material is being tested with three application levels of two commercially available microencapsulation technologies: Klean Earth Environmental Company (KEECO) and Envirobond. They are being evaluated in comparative laboratory studies using modified humidity cell operation.

Technology Description

Microencapsulation is the isolation of sulfide minerals by precipitating a chemical *coating* on unoxidized pyrite or where the material is reacted with an oxidizing agent to produce ferric ions.

The KEECO KB-SEA technology uses a soluble silica to produce an insoluble ferric silicate precipitate that encapsulates solid media particles. The materials become stabilized as this silica coating helps to control future acid generation.

The Envirobond EcoBond-ARD technology uses a soluble phosphate to form a ferric phosphate precipitate that prevents the leaching of metal contaminates by creating an impenetrable chemical bond.

Humidity cells containing three application rates (high, medium, and low) with duplicates for each along with control cells are being tested and leached weekly (see Figure 18).

Status

The control reactors had acid drainage with a pH >6 after 1 week and a pH of 3.3 at 60 weeks. Over the first 60 weeks of testing, the KB-SEA treatment was successful in preventing acid drainage; however, it must be noted that initially very high pHs were generated in comparison to the controls (see Figure 19).

The EcoBond treatment delayed the onset of acidification but was not successful in preventing acid drainage. Project testing of the EcoBond cells was discontinued at 60 weeks with one set of the EcoBond-ARD duplicate cells being sent to the technology provider for reapplication and continued leaching.

Humidity cell testing will continue on the KB-SEA treated materials. At the completion of the humidity cell testing phase, the spent test materials will undergo a microscopic investigation to evaluate the actual microencapsulation layer. Additional microscopic work will be conducted on the treated but unleached materials.

Figure 18. Humidity cell leach tests.

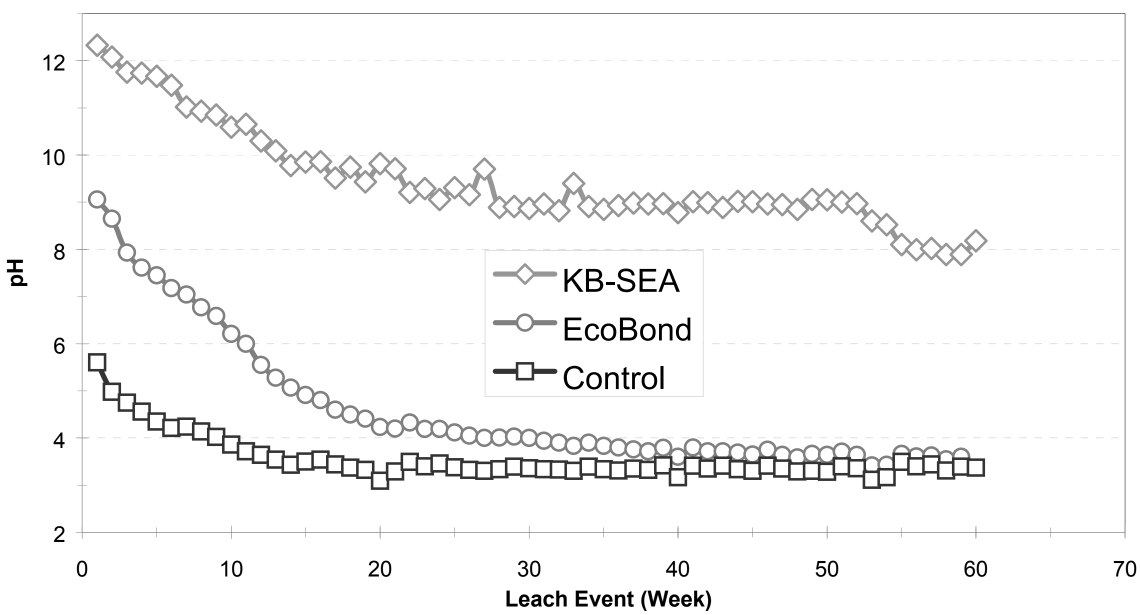

Figure 19. Microencapsulation humidity cell testing.

ACTIVITY III, PROJECT 34 BIOREMEDIATION OF PIT LAKES (GILT EDGE MINE)

Project Overview

This project is being conducted at the Gilt Edge Mine Superfund site near Deadwood, South Dakota. The project is a collaboration between the Mine Waste Technology Program and the U.S. Environmental Protection Agency's (EPA) Region VIII Superfund office. MWTP is taking the prime role in this project with support from EPA Region VIII. EPA Region VIII's interest is to conduct a treatability study as part of the site Remedial Investigation/Feasibility Study (RI/FS) process, while MWTP's interest is to develop data applicable to other similar sites. An in situ treatment of the Anchor Hill Pit, an open pit at the Gilt Edge site containing approximately 70 million gallons of acidic water containing high levels of metals, sulfate, and nitrate, is being performed. The treatment consisted of an initial neutralization step, followed by a biological treatment to further improve water quality and create a long-term, stable system. After the two-step treatment, the project would enter a monitoring mode where the pit lake would be physically and chemically characterized on a quarterly basis for several years. The purpose is to see how well the treatments work and how stable the pit lake water becomes, e.g., if metal sulfides are produced, does the system reoxidize and remobilize those metals

Technology Description

After initial chemical/physical characterization of the pit lake, the neutralization step was implemented by Shepherd-Miller, Inc. (SMI) of Fort Collins, Colorado, under subcontract to MSE Technology Applications, Inc. SMI used a Neutra-Mill fed with lime (CaO). The Neutra-Mill is simply a floating platform containing an apparatus to mix a reagent in with the water it is floating on. The Neutra-Mill was developed by Earth Systems, Pty. of Australia; SMI holds the U.S. license to apply the technology. Neutralization occurred between March and May 2001.

After neutralization, the pit was allowed to sit undisturbed for several weeks to allow precipitated solids to settle and the system to stabilize. After stabilization, the pit lake was once again characterized. Following this, in late May 2001, material consisting of methanol, molasses, and phosphoric acid was added to the pit lake. This process has been patented by Green World Science, Inc., of Boise, Idaho. The purpose of the organic carbon addition is to produce reducing conditions in the water and stimulate the activity of indigenous bacteria. This should have the effect of reducing or eliminating nitrate/nitrite and selenium, and polishing toxic metals concentrations to very low levels by precipitating them as sulfides (produced by reducing some sulfate to sulfide by sulfate-reducing bacteria activity), as well as adding bicarbonate alkalinity to the water to provide a buffering capacity.

Status

Project accomplishments in FY02 primarily include monitoring the pit water chemistry. Sampling occurred in October 2001, February 2002, June 2002, and August 2002. Overall, treatment progress has been much slower than anticipated. Nitrate concentrations slowly decreased through the year as seen in Figure 20. Original expectations were that denitrification would be complete within several months of organic addition. The slow rate of treatment was attributed to the interference of dissolved aluminum with bacterial activity, along with the buffering effect of aluminum precipitation as the pH rose due to bacterial alkalinity production. Aluminum concentrations subsequent to neutralization are presented in Figure 21. The presence of aluminum was due to a drop in pH seen during the stabilization period immediately following pit neutralization in May 2001, with associated metals redissolution. The drop in pH was due to the slow completion of neutralization reactions, or to acidic runoff entering the pit from heavy rain coupled with little or no buffering capacity in the water, or a combination of the two. As a result of the slow progress of treatment, it was decided to make an effort to modify the pit water chemistry to be optimum for bacterial activity through the winter of 2003. Therefore, in September 2002, sodium hydroxide was added to raise the pit water pH to approximately seven from an average of approximately 5.5 to 6.0, and additional organic material (molasses and methanol) was added to provide sufficient carbon to complete denitrification and the subsequent desired sulfate reduction. Preliminary results indicate that these steps were successful, with significantly decreased nitrate and aluminum levels, as well as increased bacterial counts, seen in October 2002.

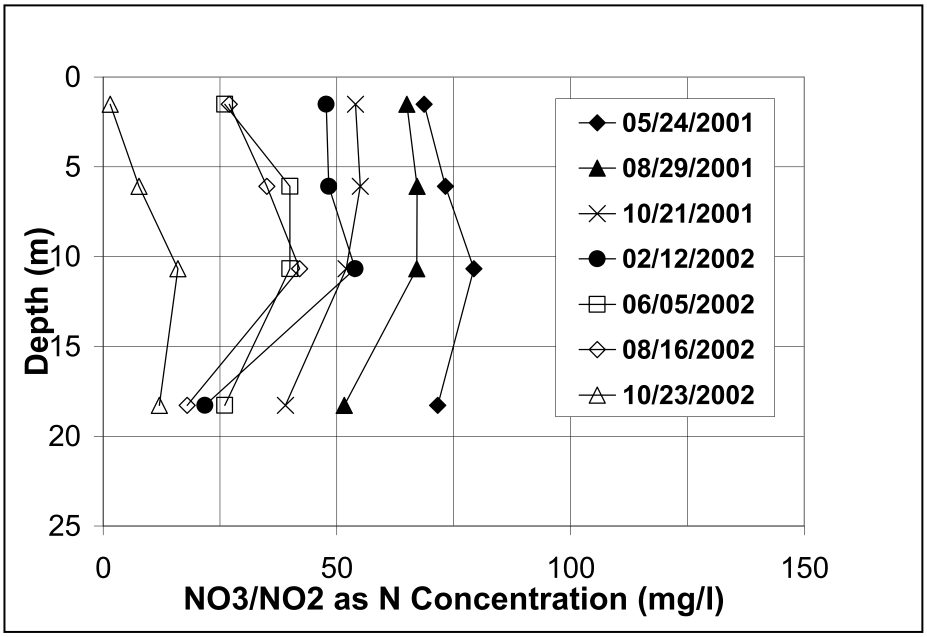

Figure 20. Anchor Hill Pit nitrate concentrations since pit neutralization.

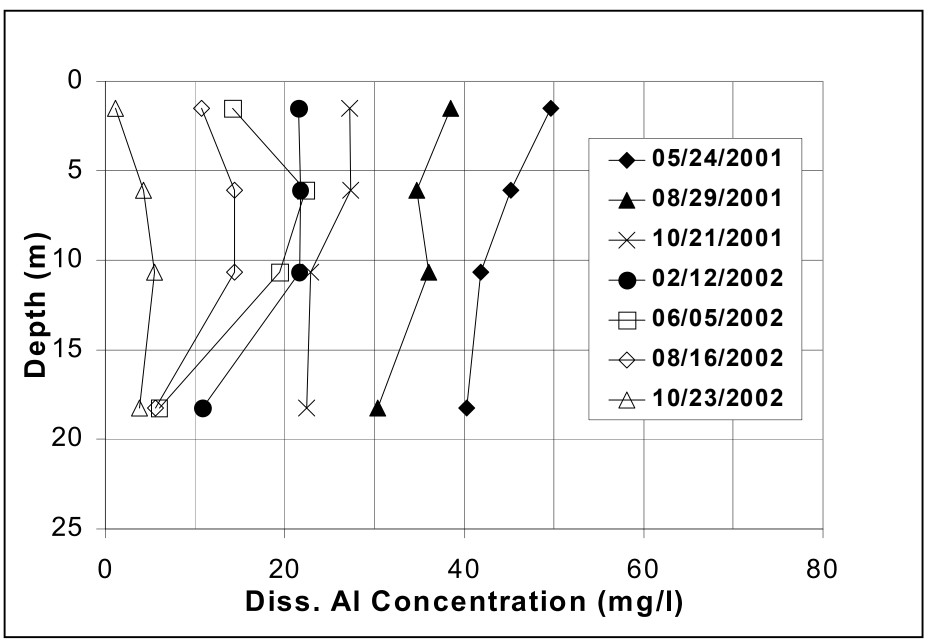

Figure 21. Anchor Hill Pit dissolved aluminum concentrations since pit neutralization.

ACTIVITY III, PROJECT 36: CERAMIC MICROFILTRATION SYSTEM DEMONSTRATION

Project Overview

The purpose of this project was to evaluate the performance of the BASX Systems, LLC Ceramic Microfiltration System (CMS) to effectively remove copper, iron, manganese, and zinc from a selected acid mine drainage (AMD). The project was divided into three phases: bench-scale scoping tests of two to four pretreatment technologies to determine those most effective in precipitating the target metals; 1-gallon per minute (gpm) pilot-scale testing of these technologies under field conditions; and designing a 300-gpm treatment plant.

Technology Description

The CMS consists of two unit operations: precipitation and solid liquid separation. Chemical/physical precipitation is not unique in treating AMD; however, when coupled with the ceramic microfilter, the BASX CMS has the potential for both technical and economic improvement in the overall handling of heavy metal precipitates. The ceramic microfilter performs the work of a conventional clarifier. As shown in Figure 22, slurry from the precipitation stage is pumped through the ceramic filter bundle. The pore size of the filters is such that water can pass through tangentially (see Figure 23) to the direction of flow; the precipitate cannot pass through tangentially and exits the end of the filter as a concentrated metal stream.

Status

The results of the bench-scale tests showed that chemical precipitation using sodium hydroxide (NaOH) and electrocoagulation (EC) using iron electrodes with the addition of potassium permanganate ($KMnO_4$) for manganese oxidation were the optimum pretreatment technologies for testing in the pilot-scale tests.

The pilot-scale tests were conducted during December 2002. Figure 24 shows the basic equipment configuration for NaOH pretreatment. The EC was configured similarly with the EC chamber being inserted between the pretreatment tank and the ceramic microfiltration pilot (CMP) with ($KMnO_4$) being fed to the pretreatment tank in addition to the NaOH. The results of the pilot-scale test (Table 5) showed that NaOH followed by ceramic microfiltration was the most effective combination for inclusion in the design for the 300-gpm CMS treatment plant.

The plant design was completed, and the project report was written.

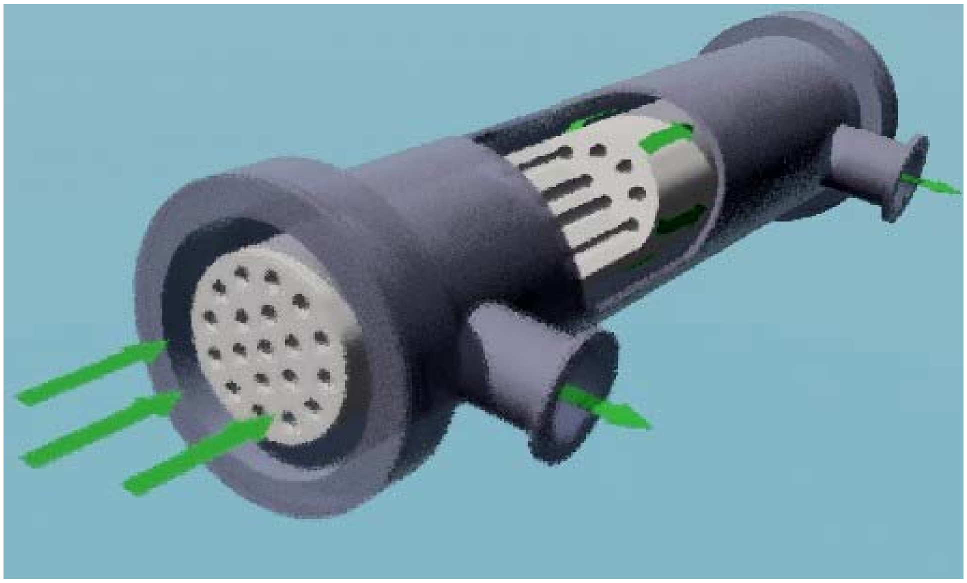

Figure 22. Ceramic microfilter bundled.

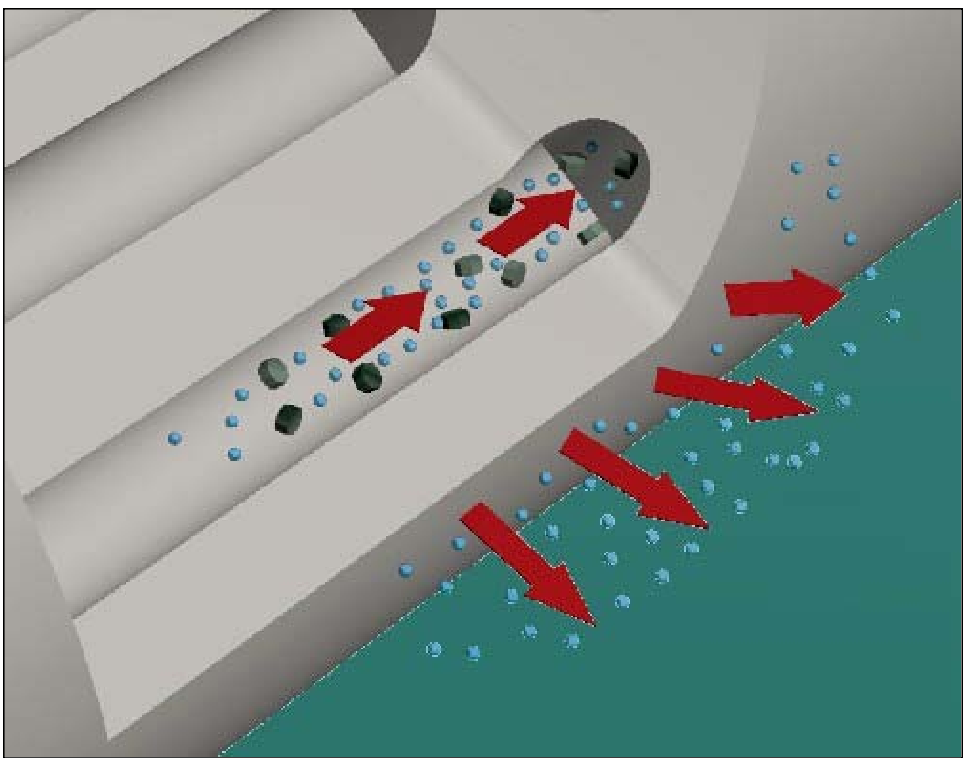

Figure 23. Cutaway view of ceramic microfilter bundle.

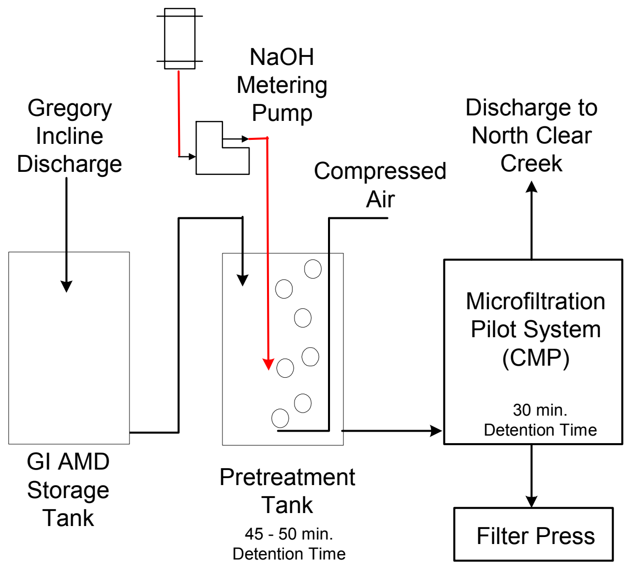

Figure 24. Simplified sodium hydroxide (NaOH) pretreatment sequence.

Table 5. Comparison of results for the Ceramic Microfiltration System pilot-scale testing.

Parameter	**Concentration in Feed (µg/l)**	**Discharge Standard (µg/l)**	**NaOH Pretreatment (µg/l)**	**EC Pretreatment (µg/l)**
Cadmium	12	7	<5	<5
Copper	780	64	<10	<10
Iron	152,700	5400	22	3210
Manganese	30,800	1000	19	35,020
Zinc	6880	740	<5	2440

ACTIVITY III, PROJECT 38: CONTAMINANT SPECIATION IN RIPARIAN SOILS DEMONSTRATION

Project Overview

This project is being conducted to evaluate phosphorus-lead soil interactions with respect to mineralogical stability. It is an investigation into the reaction processes that take place when phosphate amendments are added to riparian soils containing lead and other solid phase material (i.e., soils mineral and organic matter).

Technology Description

Phosphorus has shown excellent potential for the remediation of lead-contaminated soils and reduction of lead bioavailability. However, no existing information correlates the reaction mechanisms of lead in field remediated soils with toxicological studies on waterfowl. This project will serve to fill this gap. In addition, this project will also serve to monitor how the speciation and bioavailability of the other contaminants are affected by phosphorus-based remediation treatments.

The task will actually build upon and link to a previously initiated investigation on the ability of phosphate amendments in lead contaminated riparian soils to reduce the bioavailability of lead to waterfowl. This work was performed by the

Idaho Department of Environmental Quality (IDEQ) and the U.S. Fish and Wildlife Service (USFWS) and was jointly funded by the Coeur d'Alene Basin Commission and U.S. Environmental Protection Agency (EPA). In previous work, different soil amendment treatment technologies were applied at a field site in the Lower Coeur d'Alene River Basin.

Status

The fate of the lead in these previously remediated soils will be investigated. Experiments using advanced spectroscopic and microscopic techniques will be conducted to demonstrate the effectiveness of phosphate soil amendments to reduce lead bioavailability, solubility, and leachability through formation of low-solubility lead compounds.

ACTIVITY III, PROJECT 39: LONG-TERM MONITORING OF PERMEABLE TREATMENT WALL DEMONSTRATION

Project Overview

The objective of this project is to provide an economical technology that uses apatite as a treatment media to passively remove zinc from the water without creating significant odor problems commonly associated with apatite treatment technologies. In the initial stages of the project, under U.S. Department of Energy funding, a fully contained subsurface retention basin and treatment system was designed to capture and treat a specified volume of water discharging from the Nevada Stewart Mine. The work scoped under the Mine Waste Technology Program (MWTP) project funding included monitoring the total system and the nearby receiving stream. The MWTP was tasked with defining a baseline metals concentration and then determining the percent reduction of dissolved metals in the effluent from the apatite treatment system over a 2-year period. Flow monitored under this project include the in- and out-flows of the system, and upstream and downstream of the treatment system effluent location.

Technology Description

The Nevada Stewart Mine site is located in Shoshone County near the headwaters of the Highland Creek drainage approximately 5 miles south of Pinehurst, Idaho. This site consists of an adit and several surface waste piles. Approximately 5,200 cubic yards of mine waste were previously removed by the U.S. Bureau of Land Management (BLM) from the site and disposed in the Central Impoundment Area at the nearby Bunker Hill Site. BLM recently contoured the site to prevent erosion and further contaminant loading to the receiving stream, Highland Creek. Approximately 40 to 60 gallons of water discharge continuously from the Nevada Stewart Mine adit into Highland Creek. Analytical results indicate high levels of dissolved zinc and iron in the soils and adit discharge.

The technology deployed for this project is an apatite-based treatment media (Apatite II) that passively removes zinc from water (either surface water or groundwater). The treatment media was placed into a fully contained subsurface retention basin and treatment system (see Figure 25). Such systems, less the treatment media, are typically installed as subsurface storm water detention/retention basins where surface impoundments are not desirable because of either aesthetics or the land value. By placing the treatment media into a contained subsurface retention system, several advantages over vault and barrier systems are gained, which include:

- significant odor control;
- protection from freezing;
- protection from vandalism and damage from animals;
- ability to change out treatment media;
- ability to accurately monitor inflow/outflow and water quality to determine metals loading; and
- does not detract from the landscape.

Figure 25. Installation of the fishbone, Apatite treatment system at the Nevada Stewart Mine site.

Status

The Nevada Stewart Mine was selected for implementation of the technology in August 2002, and construction of the apatite treatment system was completed at the end of September 2002. Treatment of the Nevada Stewart adit discharge began on October 1, 2002, and the flow through the system was 18 gallons per minute.

The first baseline sample was taken in November 2002, this sample showed that the system reduced the total metals loading of zinc by 90%, iron by 90%, and manganese by 50%. An aeration process or technology would have to be incorporated where the systems effluent discharges to reduce manganese further. The aeration systems could either be mechanical, surface, or in-line aerations or a simple drain system where the effluent cascades over rocks or splash blocks increasing oxidation. System monitoring will be performed monthly until September 2004.

After the system operated for a few months, the treatment system plugged. The plugging occurred at the effluent catch basin illustrated in the lower, right corner photo of Figure 25 The geotextile fabric plugged with precipitate suspended in the effluent discharge and bypass mine water. The catch basin was opened and gravel was placed in the system to create a French drain to reduce plugging. This solution has worked effectively to reduce plugging.

ACTIVITY III, PROJECT 40: ELECTROCHEMICAL TAILINGS COVER

Project Overview

This project will be conducted at Tailings Impoundment 1 at the Golden Sunlight Mine (GSM), owned by Placer Dome, Inc., near Whitehall, Montana. The 240-acre impoundment contains tailings from the GSM mill; the tailings contain approximately 7% sulfide by weight and are covered with approximately 5 feet of soil. The purpose of the demonstration is to gather performance and cost information for the electrochemical cover technology developed by Enpar Technologies, Inc., of Guelph, Ontario, Canada. Initial project work will include conducting initial characterization work of the soil cover material and the tailings with the goal of gathering information to design the field installation; performing laboratory tests to attempt to correlate dissolved oxygen in the tailings with oxidation-reduction potential measurements;

preparing a Quality Assurance Project Plan (QAPP) for the field installation; and preparing the field installation design. If further project funds become available, the project may proceed with the field installation, which will be performed by Enpar and GSM personnel under MSE Technology Applications, Inc., oversight. The field installation will be monitored for up to 3 years, followed by a project final report.

Technology Description

This technology is intended to be an enhancement of a soil cover to greatly reduce or eliminate the oxidation of sulfide materials, thereby, reducing or eliminating acid rock drainage produced by the covered material. The electrochemical cover consists of sacrificial anodes (e.g., magnesium) overlying the soil cover, which further overlies a cathode consisting of a steel mesh. The soil cover essentially is the conductive dielectric between the cathode and anodes. Oxygen is consumed and alkalinity generated at the cathode by the reaction $O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$, with the needed electrons produced at the cathode by passive, galvanic corrosion of the anodes. The anodes can be sized so they last for as long as desired; Enpar has typically sized them so they last for 30 to 35 years.

Status

In FY02, direction was received from the U.S. Environmental Protection Agency (EPA) to initiate the project. A work plan was prepared and approved by EPA. In addition, a subcontract was initiated with Enpar for their participation in the project. FY03 plans are to complete initial characterization of the soil cover and tailings materials, complete laboratory tests attempting to correlate dissolved oxygen in the tailings with oxidation-reduction measurements; complete a QAPP; and complete the design of the field installation. If additional funds become available, the project may proceed with the field installation.

ACTIVITY IV OVERVIEW—BENCH-SCALE TESTING

The objective of this activity is to develop, qualify, and screen techniques that show promise for cost-effective remediation of mine waste. The most promising and innovative techniques will undergo bench- or pilot-scale evaluations and applicability studies to provide an important first step to full-scale field demonstrations. Each experiment is assigned as an approved project with specific goals, budget, schedule, and principal team members.

ACTIVITY IV, PROJECT 22: ORGANIC MATTER DEGRADATION RATE IN A SULFATE REDUCING WETLAND

Project Overview

The primary objectives for this project were to determine the organic matter decay rate in sulfate reducing wetlands and improve the understanding of how natural wetlands function in metals-contaminated regions. The biodegradable organic matter serves as an indirect carbon and energy source for sulfate reducing bacteria that convert sulfate in the acid mine drainage to sulfide and bicarbonate, which precipitate heavy metals and neutralize acidity. To make quantitative predictions about long-term sulfate reduction rates in constructed wetlands and solid-substrate bioreactors, an effective mathematical model for the system must exist. Sulfate reduction is needed to precipitate heavy metals, and the sulfate reduction rate determines the rate of water treatment. The rate-limiting step in biogenic sulfide production is organic matter degradation. A first order rate coefficient and quantity of organic matter are needed to predict the organic matter replenishment interval that will keep the treatment system operating properly.

Technology Description

Field tests were run in a constructed wetland at the Upper Blackfoot Mining Complex owned by ASARCO near Lincoln, Montana. The rate coefficient was measured by burying dialysis bags made of regenerated cellulose containing compost in a constructed wetland treating acid mine drainage at the Upper Blackfoot Mining Complex. For the laboratory investigation, two reactors (duplicate experiments) were filled with mushroom compost and solution containing 50 milligrams iron per liter and 500 milligrams SO_4^{2-} per liter and kept in an incubator in a laboratory at Montana Tech. Both total organic carbon (TOC) and chemical oxygen demand (COD) were measured over time in samples from the field wetland and laboratory reactors. Other parameters measured included percent volatile solids, carbohydrates, and nonacid soluble matter.

Status

This project continued from January through December 2002. No significant changes to any of five parameters (COD, TOC, volatile solids, carbohydrates, and nonacid soluble matter) characterizing compost composition occurred during the first year of the research optimization phase of a study on the degradation rate of compost in systems treating acid mine drainage through biological sulfate reduction. The same compost used in the first year will continue to be degraded and monitored in laboratory and field systems for the second year (or Phase II) of the project.

ACTIVITY IV, PROJECT 23: SULFATE REMOVAL TECHNOLOGY DEVELOPMENT

Project Overview

Numerous mine waters and process effluent waters contain elevated concentrations of sulfate above the Primary Drinking Water Standard (500 milligrams per liter) or the Secondary Drinking Water Standard (250 milligrams per liter). The objective of the sulfate removal technology project was to investigate the possibility of reducing sulfate to sulfide on a metallic surface (with subsequent precipitation of a metal sulfide) and to investigate the use of compound precipitation to remove sulfate through the formation of a solid phase. A limited number of technologies are presently used for removing sulfate from wastewater such as bioreduction of sulfate to sulfide and membrane exclusion. These technologies have several disadvantages in that they are relatively expensive to operate, require specialized equipment, require long residence time reactors (bioreduction), high pressure (membrane processes like reverse osmosis and nanofiltration), and have difficult solid/liquid separations and membrane fouling problems.

Technology Description

A total of two technological approaches for the lowering of sulfate were investigated for this project including metal reduction of sulfate and precipitation of sulfate bearing compounds. The goal of the experimental study was to achieve a sulfate concentration of less than 250 milligrams per liter.

Status

This project is currently ongoing and was recently granted an extension for completion. Various testing has been completed to investigate both the metal reduction and compound precipitation methods for removing sulfate from wastewater. To date, the compound precipitation portion of the overall study performed on synthetic waters was completed and a portion of the *real* waters have been exposed to optimized precipitation conditions. Solution samples from these tests are presently being analyzed by ion chromatography. Preliminary tests (i.e., oxidation/reduction scans) have also been completed to investigate the sulfate reduction system. Additional testing and data analysis is proceeding and a final report will be completed FY03.

ACTIVITY IV, PROJECT 24: ALGAL BIOREMEDIATION OF THE BERKELEY PIT LAKE SYSTEM–PHASE III

Project Overview

The Berkeley Pit Lake is a former open-pit copper mine that operated between 1955 and 1982. In 1982, the mine's dewatering pumps were shutoff, and the pit began filling with acidic water, which is currently rising at a rate of about 4 meters (m) per year. The Berkeley Pit Lake is approximately 542 m deep and 1.8 kilometers (km) across. In 1984, the Berkeley Pit was designated as a CERCLA Superfund site by the U.S. Environmental Protection Agency (EPA). Other important aspects of the Berkeley Pit Lake include low acidic pH values (pH 2.5 to 3.0) and high concentrations of various metals. Previous and ongoing Mine Waste Technology Program research has been investigating the intricacies of the microbial ecology of the Berkeley Pit Lake system such as the diversity of algae, protistans, fungi, and bacteria that inhabit the pit lake.

Technology Description

This project was to further investigate some of the previously isolated extremophiles (specifically algae) from the Berkeley Pit Lake system that may be used as a potential solution for bioremediation. More specifically, the project objectives were as follows: 1) to evaluate the bioremediative potential of the four most rapidly growing species in the Berkeley Pit Lake System; 2) to determine which combination of nutrients will stimulate growth of the best bioremediator of the four isolated species; 3) to determine a temperature profile for the four species to determine their optimal growth temperature; 4) to continue to isolate organisms and determine their bioremediative potential; and 5) monitor algal and bacterial counts from a profile of Pit Lake System waters.

Status

Applicable testing and data analysis is proceeding in accordance with the project objectives, and a final report will be completed FY03. Various on-going data collection activities include separating bacteria from algae by washing through a filter and centrifugation; determining metal/element uptake potential by measuring dissolved metal concentrations before and after adding microorganisms to Berkeley Pit Lake water using inductively coupled plasma atomic emission spectrometry (ICP-AES); isolating algae from soil to determine which species are present; isolating/identifying bacteria and moss from soil samples; and evaluating techniques for the rapid isolation and growth of protonema.

ACTIVITY V OVERVIEW— TECHNOLOGY TRANSFER

This activity consists of making technical information developed during Mine Waste Technology Program (MWTP) activities available to industry, academia, and government agencies. Tasks include preparing and distributing MWTP reports, presenting information about MWTP to various groups, publications in journals and magazines, holding Technical Integration Committee meetings, sponsoring mine waste conferences, and working to commercialize treatment technologies.

Fiscal Year Highlights

- The MWTP Annual Report was published summarizing fiscal year accomplishments. A similar report will be published each year.

- Several MWTP professionals appeared at varied meetings to discuss the Program with interested parties. Many mine waste conferences, as well as mining industry meetings, were attended.

ACTIVITY VI OVERVIEW—TRAINING AND EDUCATION

Through its education and training programs, the Mine Waste Technology Program (MWTP) continues to educate professionals and the general public about the latest information regarding mine and mineral waste cleanup methods and research.

As a result of rapid technology and regulatory changes, professionals working in the mine- and mineral-waste areas often encounter difficulties in upgrading their knowledge and skills in these fields. In recent years, the environmental issues related to the mining and mineral industries have received widespread public, industry, and political attention. While knowledge of current research and technology is vital for dealing with mine and mineral wastes, time and costs may prevent companies from sending employees back to the college classroom.

Through short courses, workshops, conferences, and video outreach, Activity VI of MWTP educates professionals and the general public and brings the specific information being generated by bench-scale research and pilot-scale technologies to those who work in mine- and mineral-waste remediation.

Fiscal 2002 Highlights

- *Hardrock Mining 2002,* conducted in May 2002, was an opportunity to examine and discuss current and future environmental issues shaping the mining industry with an emphasis on case study analysis and technology verification. The U.S. Environmental Protection Agency's (EPA) Office of Research and Development and EPA's National Risk Management Research Laboratory (NRMRL) sponsored the 3-day event. MWTP provided funding and sponsorship.

  Attendees exchanged scientific information serving to enhance remediation and cleanup of both legacy and current mining wastes and to contribute to a sustainable U.S. modern mining industry. NRMRL's Technology Transfer staff completed a CD that includes the conference materials, presentations, posters, and transcripts of plenary speakers. Call (513) 560-7804 to obtain the CD.

- The *Mine Design, Operations, and Closure Conference 2002,* conducted in April 2002 continued last year's interagency cooperation. The 5-day event was cosponsored by the U.S. Forest Service; U.S. Bureau of Land Management; Montana Department of State Lands; MSE Technology Applications, Inc.; Haskell Environmental Research Studies Center; several other private companies; and Montana Tech. During the conference, experts presented overviews on such topics as predictive chemical modeling for acid mine drainage, mine water quality source control, state-of-the-art containment technologies, and innovative pit reclamation. Over 130 mine operators, consultants, and professionals from the private and public sectors attended the conference.

- The Mine and Mineral Waste Emphasis Program has an enrollment of 10 students with all of them receiving funding from MWTP. This is an interdisciplinary graduate program that allows students to major in their choice of a wide variety of technical disciplines while maintaining an emphasis in mining and mineral waste.

- A group of Mine and Mineral Waste Emphasis graduate students attended the Mine Design, Operations, and Closure Conference 2002.

- A cooperative agreement is in place for work with the Haskell Environmental Research Studies Center at Haskell Indian Nations University.

- Graduate students in the Mine and Mineral Waste Emphasis Program are working on projects in Activities IV.

- As part of the Native American Initiative, Montana Tech presented five short courses: Mining and the Environment at Fort Belknap, and Acid Rock Drainage at both Fort Belknap and Salish Kootenai College. An environmental learning community was set up to house the short courses and Web courses to make them accessible to Native American communities around the country. One Web course, *Environmental Planning for Small Communities*, is on-line.

Future Activities

The following training and educational activities are scheduled for 2003:

- MWTP Training and Educational activities will offer the Mine Design, Operations, and Closure Conference 2003 in April 2003.

- MWTP is working on a cooperative education package for the Montana Department of Environmental Quality.

- All funded Mine and Mineral Waste Emphasis Program graduate students will work on mine waste-oriented projects as a part of their funding requirements.

FINANCIAL SUMMARY

Total expenditures during the period October 1, 2001, through September 30, 2002, were $3,687,532, including both labor and nonlabor expense categories. Individual activity accounts are depicted on the performance graph in Figure 26

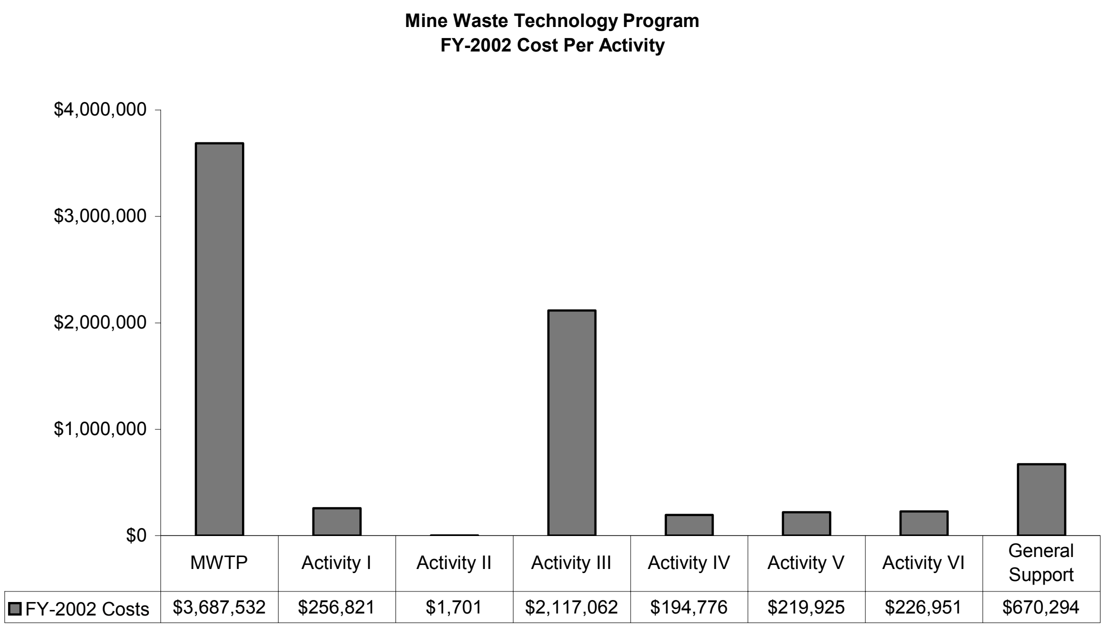

Figure 26 Mine Waste Technology Program fiscal 2002 performance graph, costs per activity.

COMPLETED ACTIVITIES

For information on the following completed Mine Waste Technology Program activities, refer to the web site: http://www.epa.gov/ORD/NRMRL/std/mtb/mwtphome.html.

Activity III

Project 1	Remote Mine Site Demonstration
Project 2	Clay-Based Grouting Demonstration
Project 4	Nitrate Removal Demonstration
Project 5	Biocyanide Demonstration
Project 6	Pollutant Magnet
Project 7	Arsenic Oxidation
Project 9	Arsenic Removal
Project 10	Surface Waste Piles—Source Control
Project 11	Cyanide Heap Biological Detoxification Demonstration
Project 12	Sulfate-Reducing Bacteria Reactive Wall Demonstration
Project 12A	Calliope Mine Internet Monitoring System
Project 13	Hydrostatic Bulkhead with Sulfate-Reducing Bacteria
Project 17	Lead Abatement Demonstration
Project 18	Gas-Fed Sulfate-Reducing Bacteria Berkeley Pit Water Treatment
Project 20	Selenium Removal/Treatment Alternatives
Project 27	Remediating Soil and Groundwater with Organic Apatite
Project 31	Remote Autonomous Mine Monitor
Project 35	Biological Prevention of Acid Mine Drainage (Gilt Edge Mine)

Activity IV

Project 1	Berkeley Pit Water Treatment
Project 2	Sludge Stabilization
Project 3	Photoassisted Electron Transfer Reactions Research
Project 3A	Photoassisted Electron Transfer Reactions for Metal-Complexed Cyanide
Project 3B	Photoassisted Electron Transfer Reactions for Berkeley Pit Water
Project 4	Metal Ion Removal from Acid Mine Wastewaters by Neutral Chelating Polymers
Project 5	Removal of Arsenic as Storable Stable Precipitates
Project 7	Berkeley Pit Innovative Technologies Project
Project 8	Pit Lake System—Characterization and Remediation for the Berkeley Pit
Project 9	Pit Lake System—Deep Water Sediment/Pore Water Characterization and Interactions
Project 10	Pit Lake System—Biological Survey of Berkeley Pit Water
Project 11	Pit Lake System Characterization and Remediation for Berkeley Pit—Phase II
Project 12	An Investigation to Develop a Technology for Removing Thallium from Mine Wastewaters
Project 13	Sulfide Complexes Formed from Mill Tailings Project
Project 14	Artificial Neural Networks as an Analysis Tool for Geochemical Data
Project 16	Pit Lake System Characterization and Remediation for Berkeley Pit—Phase III
Project 17	Mine Dump Reclamation Using Tickle Grass Project
Project 18	Investigation of Natural Wetlands Near Abandoned Mine Sites
Project 19	Removing Oxyanions of Arsenic and Selenium from Mine Wastewaters Using Galvanically Enhanced Cementation Technology
Project 20	Algal Bioremediation of Berkeley Pit Water, Phase II

KEY CONTACTS

U.S. Environmental Protection Agency:

Roger C. Wilmoth
U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
26 W. Martin Luther King Drive
Cincinnati, OH 45268

Telephone: (513) 569-7509
Fax: (513) 569-7471
wilmoth.roger@epa.gov

U.S. Department of Energy:

Madhav Ghate
U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 880
3610 Collins Ferry Road
Morgantown, WV 26507-0880

Telephone: (304) 285-4638
Fax: (304) 285-4135
mghate@netl.doe.gov

MSE Technology Applications, Inc.:

Jeff LeFever, Program Manager
MSE Technology Applications, Inc.
P.O. Box 4078
Butte, MT 59702

Telephone: (406) 494-7358
Fax: (406) 494-7230
jlefever@mse-ta.com

Montana Tech:

Karl E. Burgher, Montana Tech MWTP Project Manager
Montana Tech of the University of Montana
1300 West Park Street
Butte, MT 59701-8997

Telephone: (406) 496-4311
Fax: (406) 496-4116
kburgher@mtech.edu

Printed on recycled paper with soybean ink